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URBAN TERRAIN ZONE CHARACTERISTICS

Richard A. Ellefsen
San Jose State University

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The purpose of this study is to support the data requirements of today's MOUT planners and scientists engaged in weapons development and combat development studies. Thirteen representative cities were selected from four major regions: Europe, Mediterranean-Middle East, Asia, and Latin America. The cities were selected for location and importance, and as good cross representation of other cities. Their terrain zones were measured, mapped, and analyzed for spatial phenomena, as well as types, heights, and construction of buildings.

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EXECUTIVE SUMMARY

This study applies a new and highly discrete system for classifying homogeneous units of terrain within the urban (MOUT) environment. The system, refined for this report, was introduced by the author in conjunction with the development and use of a computer-assisted game (ACABUG) for combat development studies initiated by U.S. Army Training and Doctrine Command's (TRADOC) System Analysis Activity (TRASANA), White Sands Missile Range, NM. The system used here represents an attempt to identify and understand varying patterns of urban terrain that would be encountered in MOUT activity anywhere in the world. Previously employed systems have either been restricted to the west European theater or were developed (as long ago as World War II) for special purposes such as assessment of aerial bombardment damage. The study is specifically dedicated to supporting the data requirements of today's MOUT planners and scientists engaged in weapons development and combat development studies.

Distinct steps were followed in obtaining and analyzing the data produced in the study. First, representative cities were selected from the four major regions to be sampled: Europe, Mediterranean-Middle East, Asian, and Latin American. The European group consists of Helsinki, Finland; Braunschweig and Stuttgart, West Germany; and Vienna, Austria. In the Mediterranean-Missile East area are Athens-Piraeus, Greece; Beirut, Lebanon; Tel Aviv-Yafo, Israel; and Tunis, Tunisia. The Asian cities are Kuala Lumpur, Malyasia; and Colombo, Sri Lanka. Latin American cities are San Jose, Costa Rica; Panama City-Balboa, Panama; and Caracas, Venezuela. Visual imagery and maps were obtained for each city. Territory studied within each city was, as nearly as data coverage allowed, the contiguously built-up urban and suburban area.

The second step consisted of delineating the urban terrain zones on maps of the city. Zonal identification was determined from image interpretation and supported by visits to all but one of the cities to determine "ground truth." Nearly all the urban terrain zones have numerous occurrences within each city. The term zone is defined here to indicate areas of homogeneous types of urban terrain. Once delineation was completed, individual thematic maps were created of each zone in each city. Each map is reproduced and appears in Appendix C.

Measurements (in hectares) of each zone were then made and tabulated. Tables were prepared that summed data by each city and totaled by region for all the study cities.

These data were analyzed and aggregated in various ways, for example, whether buildings within zones were attached or detached and by functional use, such as residential, commercial, industrial/storage, etc. Ranking each zone, in accordance with its area covered, was also done in order to aid understanding the nature of the MOUT environment.

The search for replicative patterns of the zones was furthered by the creation of a series of thematic maps of single functions of selected urban terrain zones. Each was compared and analyzed.

Several findings could prove to be significant to MOUT planners. One is the measurement that, all together, about two-thirds (69.6 percent) of the area of all urban terrain (including open spaces) has buildings that are detached from one another. The commonly expressed concept of urban terrain consisting mainly of attached buildings aligned along "street canyons" and therefore causing severe problems for personnel and vehicle movement (masking, restrictive arming distances, etc.) is applicable in only about one-fifth of the total area of the city, (even though this portion almost invariably contains the tallest buildings and a city's most valuable and significant real estate). These data, summed by city and aggregated by region, provide a further level of information. For many terrain zone classes, little variation is seen from one region to another indicating the universality of the characteristics of the urban environment. The identification of situations where zonal variation is significant is potentially useful to MOUT scientists in making regional adjustments to the universal generalizations.

The data are also aggregated by functional use in order to provide a familiar base. In a general way, 63.8 percent of the area of cities is taken up with residential land use. Industrial/storage is the next most important, with 14.1 percent of the total, while commercial uses, in total, form only a perhaps surprisingly small 2.5 percent of total area.

Especially important is the finding that only 1 percent of the total aggregated area of cities is consumed by the most significant and treasured area of all, the city core. Of course, if floor space were to be considered, this area of high-rise buildings would account for a fairly high proportion of the total floor space of a city. Also, the tall buildings of the core area impart a distinctive character to the urban environment, one that provides a unique set of both advantages and disadvantages to either attackers or defenders.

Analysis of a series of single thematic maps of selected terrain zones provides a base for the development of urban spatial models that could be extremely useful in MOUT planning. Each of the sets of zonal maps conveys useful generalizations. To wit, the core areas of cities are not always located at the centroid of a city but rather are found at points that were most central at the time of a city's early development. For instance, for port cities, these cores developed at the waterfront and, with few exceptions, have not migrated to another part of the city even though the built-up area has increased several fold. Likewise, railroad and dock-related industrial/storage areas are found in earlier developed sections of the city, mainly at the periphery of the core areas, where docks and railroad lines serve (or did serve) the core. The modern open-set apartment complexes are located invariably at fairly great distances from the core on land parcels large enough for planned developments. They form a loose ring at the edge of most of the cities.

As might be expected, the areas of low density, detached single-family houses, are virtually all found at the outermost edges of the built-up area. The administrative/cultural centers, by contrast, are the most evenly distributed of all zonal classes because they consist of the concentrated core to the remarkably evenly distributed elementary and secondary schools.

In addition to the mapping, measuring, and analyzing of the terrain zones as spatial phenomena, the types and heights of buildings within the zones were also studied and recorded. Mass construction buildings form a majority in some zones while framed buildings dominate in other zones. As would be expected, mass construction is the mode in the older attached and detached houses zones. These structures also form the majority in the detached, but close-set, low-rise apartment zones. Framed construction buildings, however, form the majority in all three subtypes of the industrial/storage zone. They are also dominant, as anticipated, in the detached, open-set apartment zone, in the core periphery zone, and in the administrative/cultural zone.

Urban terrain zones also have distinctive characteristics of building height. The zones of tall buildings are the core areas, their peripheries, planned detached apartment complexes, and outer cities. The zones with low buildings are those of truck-related detached industrial/storage, houses, commercial ribbons, and administrative/cultural uses.

Detailed measurements are provided for buildings of the core areas of the studied cities. Data are given on building construction type, building height, and texture of outer wall surfaces. Framed buildings (heavy clad and light clad combined) form 60.3 percent of the total. Despite the image of core areas being tall, on the average for all the cities, only 22 percent of all core area buildings are over eight stories high. The most common height is three, four, and five stories. Surface texture is a related feature. Many of these buildings are of mass construction, and according to common practice, have had plaster placed over the bricks to protect them from weathering. Over 60 percent of the core area buildings are plastered. The remainder consists of decorative brick, stone veneer, glass, and composition material.

The following conclusions were reached:

- Though many conditions vary widely for cities around the world, a positive sense of order and replication exists for the urban terrain zones of these cities.

- Urban terrain zones and building types of these cities are readily classified in accordance with a universal scheme.

- The study cities are remarkably similar in the physical characteristics of their buildings and terrain zones despite visual differences in architecture.

● Interpreting remotely sensed imagery, supported by "ground truth" observations, is a valid method of acquiring highly detailed data.

● Field observations indicate that the principles concerning MOUT usage of buildings (developed in the Training Aids publication [Ellefsen, Carlson, Thein, Milligan, Lein, & Kanemoto, 1981] are applicable to the study cities).

● The urban terrain zones delimited in the study are at near the optimum level of generalization to serve the needs of a variety of MOUT studies.

● Variations in cities from region to region are caused, to a considerable degree, by differences in level of economic development and cultural preferences.

● Development of a spatial model can be achieved by expanding and using the single urban terrain zone thematic maps. Such a model has a high potential value for future MOUT studies.

● The extensive spatial expansion of cities throughout the world in the last three decades has significant ramifications for MOUT. One is the greatly increased use of reinforced concrete framed construction in all parts of cities. This is only one expression of the pronounced trend to using ever lighter construction in the last century. Another is the construction of such related urban terrain zones as detached, high-rise apartments, truck-related industrial/storage zones, and shopping centers. These have the effect of producing a somewhat sharper edge to the periphery of the city than is the case with unplanned incremental expansion composed primarily of houses.

These lead to the following recommendations:

● MOUT planners should develop a data base (containing information on terrain zones, buildings, etc.) for a large number of international cities where threat situations could occur. Such a base would be useful both to general theoretical studies and to the development of a discrete inventory.

● Develop a general spatial model of the urban terrain zones of cities with variations of the model for the different regions.

● Prepare contingency planning for the new type of features encountered in the ever expanding peripheral areas of cities, the region loosely and misleadingly referred to as the suburbs.

● The data acquired and the knowledge gained of the characteristics of the MOUT environment should be transmitted to the entire MOUT community in general and to branches of the U.S. Army in particular.

● The concept of urban terrain zones should be directed to MOUT planners, especially those in combat development and weapons development. These zones could serve as elementary building blocks in the development of specialized techniques and variations of weapons. The MOUT environment is significantly varied from place to place within the city and these differences should be incorporated into thinking about urban combat. The urban terrain should not be treated simplistically. Each urban terrain zone has advantages and disadvantages.

URBAN TERRAIN ZONE CHARACTERISTICS

INTRODUCTION

Scientists engaged in weapons development or combat development studies have a general need for information about the environment as a significant design parameter; an example would be the effects of deserts and jungles on equipment. A special need exists for detailed information on the nature of the urban terrain, for studies generally classed under the heading of Military Operations on Urban Terrain (MOUT).

The principal purpose of this study is to add to the existing MOUT data base pertinent information about the urban environment in 13 selected urban areas from around the world representing several broad environments. Representing the Northwest European urban environment are the cities of Helsinki, Finland; Braunschweig and Stuttgart, West Germany; and Vienna, Austria. The Mediterranean-Middle East area is represented by Athens-Pireaus, Greece; Beirut, Lebanon; Tel Aviv-Yafo, Israel; and Tunis, Tunisia. Asia is represented by Kuala Lumpur, Malaysia; and Colombo, Sri Lanka. Latin America is represented by San Jose, Costa Rica; Panama City-Balboa, Panama; and Caracas, Venezuela.

The information presented in this report, gathered specifically to support weapons development work, consists primarily of the two major items of 1) delineation and description of the urban terrain zones of the study cities; and 2) the types of buildings and their characteristics found in those zones. The data gathered in the course of the study (both in field work and in interpretation of aerial imagery) are analyzed and generalized upon with a view toward characterizing urban terrain generally and in broad regions of the world specifically.

The study is an extension of work done earlier by the author and collaborating colleagues. The first probe into the character of the urban terrain was published as part of a broad study supported by the Advanced Research Projects Agency (ARPA), now DARPA, and appeared under the title of Military Operations in Built-up Areas (Ellefsen, 1973). A later study (Ellefsen, Coffland, & Orr, 1977) began an inquiry into buildings, as an integral part of urban terrain, that continued in several later works. One of these works, Urban Terrain Analysis Training Aids (Ellefsen, Carlson, Thein, Milligan, Lein, & Kanemoto, 1981), provided specific data on building characteristics that were later incorporated into U.S. Army Field Manual 90-10-1, An Infantryman's Guide to Urban Combat (Department of the Army, 1980).

The information provided in these studies has also been used in support of the modeling of urban terrain for combat development studies. Interest in the subject has been expressed both within the U.S. Army and internationally for the four English speaking countries (the United States [America], Britain, Canada, and Australia, the ABCA countries). The four countries collaborated on a Quadripartite experiment with urban terrain modeling. One product of this joint effort was the development of a system of classifying both the building and the zones, as components of the urban terrain, one that can lead to standardization of terms for the purpose of

enhancing communication among the armies of the four countries. The study (Ellefsen, 1983) was published by TRADOC Systems Analysis Activity (TRASANA) under the title of American Canadian Australian British Urban Game (ACABUG) Urban Terrain Classification System. The classification system introduced in that document is applied in this study.

METHOD

A method had to be devised to examine objectively the physical characteristics of the urban environment. Because these physical characteristics deal with form--in the form of patterns of zones, streets, open space and other spatial items, and in the buildings that occupy these urban surface spaces--the term morphology, or literally form or shape, was adopted and is used throughout this document. The term is used to make clear the separation from function, the use to which buildings and not built-upon surface is put. The contention is made that the form and shape of the city are of far greater importance in a combat situation than is the civilian usage of the city in a precombat environment.

The notion of form and shape is of vital importance in making a distinction between urban terrain and nonurban terrain. Urban terrain, being a man-made environment, is composed of angular forms, the like of which occurs only rarely in nonurban terrain. Not only are these forms angular in planimetric pattern (as a grid street pattern) but in the third dimension as well. Verticality becomes of great importance, for this not only creates extremely difficult barriers to assault, but provides the defense with a man-made form of "high ground." A large city provides several planes of "urban high ground" and, in many instances, a subterranean level in addition. Moreover, the multiplication of surface space in the form of multistory buildings, means that even though the total area of cities is not very great, the aggregate total surface space (the floor area) on which combat could occur is several times greater than the surface space as shown on a map and represents a sizable area when totaled. From the viewpoint of the defender, this urban space is both large and complex in its characteristics. Further considering the concealment and cover possibilities provided by buildings, there is little cause for wonder at the frequently quoted statement that urban terrain is a force multiplier to the defenders.

Procedural Steps Employed

The method involved for all of the cities examined is detailed below.

Development of the classification systems. A prerequisite step in the development of the system was the identification of order in the urban universe. Considering that cities are composed of buildings, streets, and other man-made features, the call for finding order can best be subdivided into the three basic steps of 1) developing a system to classify types of building construction; 2) developing a system for classifying urban terrian zones within the city; and 3) delineating these zones on large-scale urban maps. Thus, two major classification systems

were formed, one for building construction types (see Appendix A), the other for urban terrain zones. The method for classifying buildings evolved during the course of several projects (as presented in two major monographs, one Urban Building Characteristics, Setting and Structure of Building Types in Selected World Cities [Ellefsen, Coffland, & Orr, 1977]; and the other, Urban Terrian Analysis Training Aids [Ellefsen, Carlson, Thein, Milligan, Lein, & Kanemoto, 1981]). The method for classifying urban terrain zones was designed while the author was engaged in the ABCA project at TRASANA and was published primarily in American Canadian Australian British Urban Game (ACABUG), Urban Terrain Classification System (Ellefsen, 1983).

In this study, these systems were used to delimit the urban terrain zones of each city and to record building types found therein. This was achieved by performing photo interpretation techniques on visual imagery of the study cities; resolution of the imagery was fine enough to see revealing characteristics of buildings and their settings. To support the interpretation of the images, all but one city (Beirut) was visited to gain "ground truth" information. This information supported and corroborated image interpretation and provided additional data on such features as the nature of building construction materials.

The urban terrain zone classification system (Table 1) used is as given below. The system is designed around the concept of progressively more complex levels. Level I, the most general, makes the primary distinction between zones where buildings are attached to each other with little or no setback from the street from zones where buildings are detached from each other. Within this detached class there are those where there is but little distance (a few meters) between structures and those where a considerable amount of distance separates buildings. Level II, the heart of the classification system as used in this study, provides accounting for zones that are distinctly different from each other both in overall pattern and in types of buildings occupying them. Level III, used only in one instance in this study, provides for yet more detail and subdivision of broader classes.

Urban Terrain Zones: Definitions

Urban terrain is not the same in all parts of the city. Downtown areas--with their tall buildings set close to each other--are obviously very different from industrial areas and from sections of single-family detached houses. These differences cause great variation in the important military considerations of cover, concealment, deployment, maneuver, etc.

In the following sections, a classification of urban terrain zones is presented, one that has proven to be suitable for the study cities and others examined elsewhere by the author. Extrapolation suggests that the urban terrain zones used here are applicable everywhere.

Table 1

Urban Terrain Zone Classification System for MOUT Studies

Class Levels		
Level I	Level II	Level III
A Attached	A-1 Commercial offices, retail, etc.; core area; low- to high-rise; mass and framed construction; to present	
(Attached buildings, little or no setback, "Urban Form")	A-2 Apartments/hotels; near core area; virtually complete filling of block frontage; 4 and more stories high; mostly pre-World War II	
	A-3 Apartments and abutted-wall houses; adjacent to core area; fewer than 4 stories; mostly pre-World War II	
	A-4 Industrial/storage; near core area; on ordered blocks with little or no setback; medium-rise; mass and framed construction; mostly pre-World War II	
	A-5 Commercial ribbon development; on some arterials outward from core and elsewhere; virtually complete filling of block frontage along street; low- to medium-rise (to 5 stories); to present	
	A-9 Commercial residential only slightly modified old city core; near modern core; commonly 2-6 stories; (example, European Medieval, Middle East Medinas)	

(continued)

Table 1 (Continued)

Urban Terrain Zone Classification System for MOUT Studies

Class Levels		
Level I	Level II	Level III
D - Detached (Detached buildings [set back from street with rear to rear and lateral separation from neighboring structures--"Rural Form"]; two levels of building concentration, close-set and open-set)	Dc1 Commercial office; core area; high-rise; light-clad framed; post-1945	
	Dc2 Residential apartments/row houses, 75% and more block frontage; varying locations; to present	
	Dc3 Residential houses, 75% and more block frontage; varying locations; to present	
	Dc4 Industrial/storage, linear building pattern; railroad or dock-related; low-rise; to present	
Close-set c	Dc5 Commercial office ("Outer City"); at metropolitan area periphery; high-rise; light-clad framed; post-1945	
	Dc7 Residential dominant, former nucleated agricultural village; at city periphery (sometimes engulfed); low-rise; old construction	
	Dc8 Residential "Shanty Towns" (e.g., Bidonvilles); city periphery locations; temporary construction; low-rise; post-1945	

(continued)

Table 1 (Continued)

Urban Terrain Zone Classification System for MOUT Studies

Class Levels		
Level I	Level II	Level III
D - Detached Open-Set o	Do1 Shopping Centers; beyond core; low-rise, mass construction dominant; post-1945	
	Do2 Residential apartments and row housing, less than 75% block frontage; low- to medium-rise; varying locations; low- to high-rise; post-1945	
	Do3 Residential houses, less than 75% frontage; low-rise; varying locations; to present	Do31 Week-end houses (Huten) located in public leased areas in Germany
	Do4 Industrial/storage, truck-related; varying locations; ordered pattern within zone (buildings fairly evenly spaced, separated by parking lots, storage area); low-rise; post-1920's	
	Do5 Commercial ribbon development; along some new arterials; open pattern (buildings separated by intervening parking lots and open storage areas); low-rise (fewer than 5 stories); post-1945	
	Do6 Administrative/cultural (e.g., government, schools, hospital complexes); low- to medium-rise; varying locations; ordered building pattern; to present	

Why is it that cities may be readily divided into distinctive zones? The answer lies in the fact that people in cities everywhere react in about the same way to universal economic conditions or problems. In the case of urban terrain zones, the response to the cost of land on which to erect city buildings is always the same. First, the cost of land in cities is the greatest at the point in the city that has been or is currently the easiest to reach. Such points are ordinarily located where major roads intersect. The alignment of these roads is, in turn, determined either by some natural funneling (as a road along a river) or by some condition that prevailed during the early development of a city.

These points that are the most easily reached (most accessible) provide the means for people to get together to conduct the most important function of a city--the exchange of goods and services. The center is thus the optimum place for people to communicate with each other. In these core, or "downtown," areas are found the main commercial, banking, cultural, entertainment, and government activities.

Because of the concentration of these activities, the limited amount of land available quickly attained very high values. (Downtown land is so expensive that it is commonly sold by the "front foot"--the frontage on the street--in U.S. cities). The cost of land was so high that little or no unbuilt-upon ("open") space could be conceded. Each building had to occupy all the available land on its lot to justify the high cost of the land. Even more important, builders quickly found that the ground surface could be multiplied by the construction of multiple story buildings. This reaction is carried to extremes in the downtown areas of today's cities with their buildings reaching 50 stories and more above ground and 3 or 4 stories below ground.

Everywhere else in cities, land values are lower than in the downtown area. Accordingly, buildings are shorter and often do no use all the surface of the lots they occupy. A city generally has its highest land values (and accordingly its tallest and most densely spaced buildings) in the core area. Land values are progressively lower in going from the city core to the edge of the suburbs. Building height and density fall off accordingly (with some exceptions to be looked at later) so that the profile of a city looks something like a pyramid although one where the slope is very steep at the center but shallow farther out.

While varying land values account for most of a city's zonal pattern, some other conditions are also at work. Some city activities, such as industry, are located where transportation is easiest, as along railroad lines or at dockside. Many modern industrial centers--those that depend mainly on truck transportation--are often located at junctions of major highways at the edge of the city. Some other types of urban terrain zones, such as administrative/cultural land uses, owe their locations to governmental decisions and not to the market value of the land.

Larger cities have urban terrain zones that are both larger and more well-defined than those in small cities. Obviously, the core areas of larger cities cover more area and usually will have taller buildings than counterpart areas of lesser cities. Apartment house zones, industrial/storage zones, and others follow the same pattern.

Explanation and Examples

The classification system presented in Table 1 is subdivided into three Levels: I, II, and III. Level I simply divides 1) the urban terrain zones whose buildings are attached from those, 2) where the buildings are detached (from each other). The detached building class, in turn, is subdivided into those detached buildings that are quite close to each other (Dc classes, detached, close-set as opposed to those that are set apart from one another (Do classes, detached, open-set).

The Level I distinction between attached and detached is of extreme importance to military operations. The zones of a city with attached buildings are those that are either in or near the core of the city where land values are so high that all surface space is covered by buildings. In these areas, the main nonbuilt-upon space is that of the city streets themselves. Combat in these areas could be conducted mainly 1) in the streets, 2) within the buildings, or 3) between opposing forces, one located in the buildings, the other in the streets. Only small areas of open space are found in the attached building zones and these are in the form of small parks, parking lots, etc.

In the zones having detached buildings, the open space lying among the buildings could be involved in a combat situation. Possibilities appear then for dismounted infantry and even vehicles to use surface space other than the streets. This concept is indicated by the use of arrows in the models of each urban terrain zone.

With the detached building zones, there is also the opening up of two more sides of the buildings; in the attached building zones there is only the front side (the side facing the street) and sometimes, but not always, the rear of the buildings facing an open court or an alley. Detached buildings have four (or more) exposed faces. This means that the number of possible firing positions from within a building is at least twice that of attached buildings and, at the same time, increases exposure to being fired upon from all sides.

The remaining levels--II and III--give more detail. Level II contains the subdivisions of Level I. These zones are found in cities all over the world, although not all zones are found in all cities. Level III is used to cover specialized local types of situations that can occur, for instance, when local custom or culture is followed in city construction or when an area favors a certain local type of building material. Two examples of Level III are given.

Level II is the part of the classification system of greatest use to ground military operations. The title of the classes of this zone consist of a) the use of buildings in the zone; b) the zone's location within the city; c) the main type of building construction found there; and d) the period in history during which the zone developed. Each of these is important in the development of a MOUT planner's understanding of the urban terrain. Each point will be taken up in order in the following material.

The use of buildings of a zone is given first because it is the most familiar and can serve as a ready reference. It also provides some indication of what the interiors of the buildings are probably like. Knowing these things, the MOUT planner can begin to forecast some of the opportunities and some of the problems that might arise from either the offensive or defensive point of view. Important distinctions are also seen in building interiors. For instance, differences in room sizes between offices, industrial/storage buildings, and houses have a bearing on whether or not certain weapons might be fired from within them.

The second item, the location within the city, gives a quick indication of where to expect such features regardless of the city encountered. Some, such as the core, railroad and dock-related industrial/storage areas have easily predictable locations when examining an unknown city. Others, such as the zone where apartment houses are predominant, appear at varying locations.

The third item in the classification system, the physical characteristics of buildings found in the zone, is a good indication of what can be expected in such important items as concealment and cover possibilities, and weapons deployment. The general heights of the buildings are indicated (low-rise, one and two stories; medium-rise, three to five stories; and high-rise, above five stories). For these classes where a single type of building construction is found nearly everywhere throughout the zone, that building type is listed (details on building types are given in Appendix A).

The fourth item, the age of most of the construction of the zone, is related to the building type. Some zones contain only old building types, in others only new structures are found, and some ("to present") have experienced a constant replacing of older structures with new.

Thus, each zone in the system has a set of characteristics that makes it different from all other zones and each is a distinctive urban environment or urban terrian zone. Its unique combination of characteritics causes it to have, in turn, a special set of opportunities and constraints relating to military operations. In the case of each zone, there is a certain mix of building types (in some instances, a single type dominates), a certain density of buildings (affecting, for example, lines of sight, engagement ranges, and weapon arming distances), a certain

pattern of street width and configurations, a generalized land-use pattern, and a common history. These points will become evident for each of the zones as they are described below.

Zones with Attached Buildings

Buildings in this group of zones are abutted to one another along the street, have little or no setback from the sidewalk, and occupy all or nearly all of the lot on which they sit. Any movement, mounted or dismounted, is effectively channeled onto the streets or through or over the buildings themselves.

The Commercial Core (Class A1). The zone (see Figure 1) is the heart of the city, the downtown, or central business district or its equivalent in another language. It is that area of a city having the densest concentration of multistory buildings. A variety of construction types is found. A common situation is to have brick buildings in the oldest part of the zone, framed, heavy-clad structures in the next to oldest part, and a concentration of framed, light-clad buildings in the newest part. In German cities, and others with repaired war damage (London is a good example), framed light-clad buildings have been built on the sites of destroyed brick buildings.

The zone is of great value to any city. It is the headquarters for commercial/financial activity and usually has important cultural and governmental buildings. Its defense is important simply because its loss would be catastrophic to the economy and to governance. These zones can be thought of as the civilian counterparts of a military headquarters.

Urban terrain in this zone provides many opportunities for defending forces. At many places within such a diverse stock of buildings there can be found areas providing a high degree of cover, possibilities for weapon deployment, and the conducting of combat support services. Also of importance, this zone has the greatest quantity of subterranean features of all the zones. Also, significant underground features exist in the form of basements, underground parking, and sometimes underground shopping areas, and transportation facilities.

Apartment/Hotel Core, Four Plus Stories (Class A2). This zone (Figure 2) consists of medium to tall apartment buildings and is normally situated just beyond a city's commercial core zone. Land value is still high so buildings must use all their lot space (that is, be attached to one another). Further, surface space is multiplied by its buildings that are four and more stories tall. Block after block in this zone is covered with buildings with little or no open space in between.

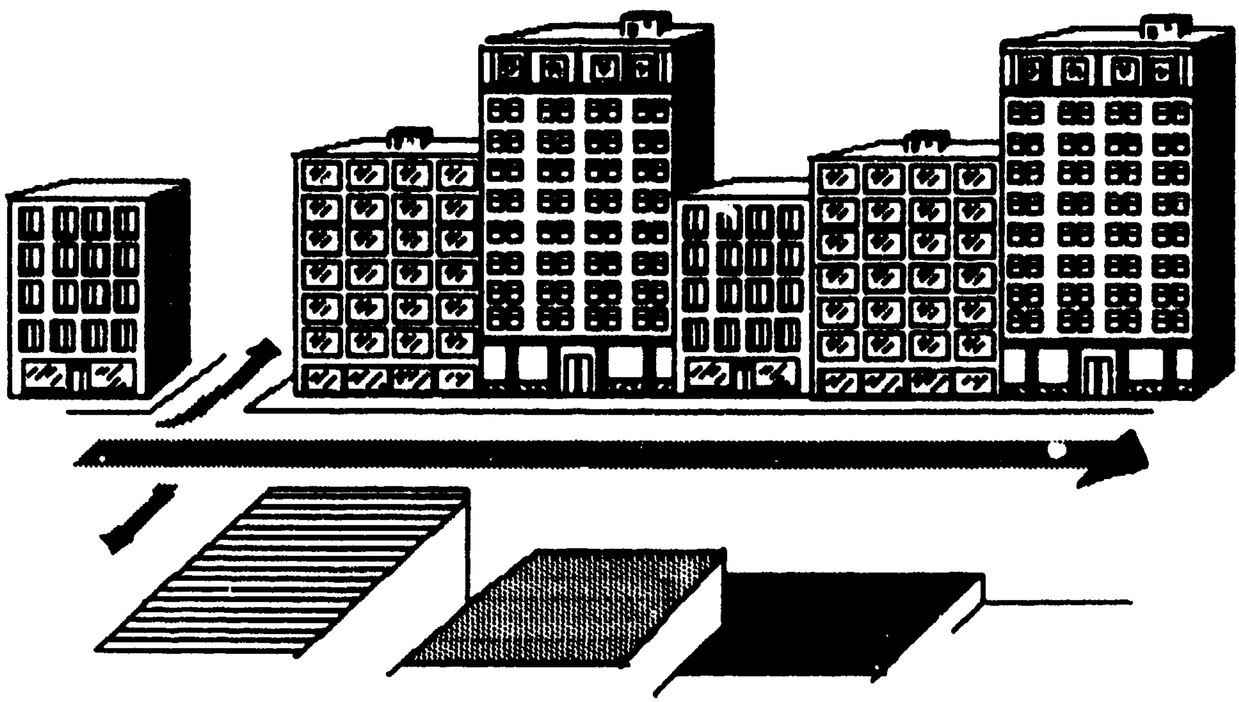


Figure 1. Urban terrain zone A1 (core area).

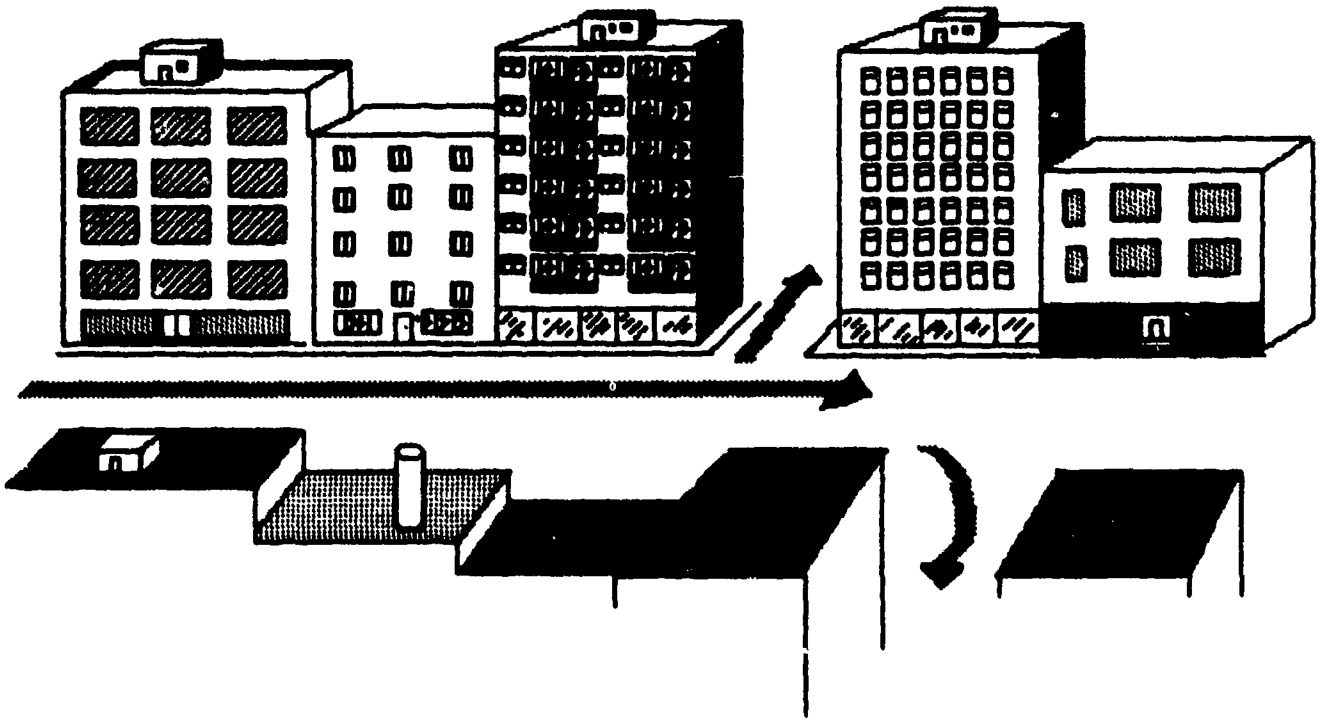


Figure 2. Urban terrain zone A2 (apartments, hotels, core periphery).

Because these zones have occupied the same area for a long time, all three of the basic construction types--mass, heavy-clad, and light-clad framed buildings--are present.

Because nearly all the buildings in this zone are apartments, urban terrain is nearly uniform throughout. This creates a condition where no building has special advantage over any other in concealment, weapons deployment, or other military considerations. The previous zone, by contrast, has a wide variety of environments within and thus far more military usage possibilities.

Apartment/Row Houses, Four Stories and Lower (Class A3). This class (Figure 3) has buildings that are somewhat lower in height than the previous class but they are still attached to each other; pedestrians and vehicles are still restricted to the street.

These zones are large in area, frequently covering tens of blocks. They are characterized by the monotonous rows of apartments and row houses facing virtually every street in the zone. Only a few open spaces exist, such as parks, and school grounds. Buildings commonly have continuous backyards along which dismounted infantry troops could pass. These open spaces, however, are often sealed off from the street and are thus not accessible by vehicles. An exception is the hof or courtyard type of apartment seen in Europe that has "tunnel" connections through the buildings from the street to the courtyard.

Industrial/Storage, Ordered Blocks (Class A4). This is the first of three very different types of industrial/storage zones (see Zones Dc4 and Do4). In this zone Figure 4, the buildings are attached to each other and cover most of the lots on which they sit. Land values in this zone, being adjacent to the downtown, are too high to allow buildings to be detached.

Buildings in this zone are strong, thanks to the need for heavy construction to support industrial and storage activities. Construction is usually either mass (mostly brick) or framed heavy-clad. Floors are also stout. Cover ranges from medium to high. In addition, the usually large, unpartitioned interior spaces offer no restriction to deploying "back blast" weapons. The large industrial type space within structures could also serve as vehicle storage and repair.

Because buildings occupy most or all of a block's surface, line of sight is short being limited to across and along streets. Also, the often uniform height (about five stories) of these attached buildings causes masking of the street from incoming artillery and from air-to-surface attack.

Commercial Ribbon Development, Some Arterials (Class A5). The practice of erecting attached buildings to get the most out of high-value land continues along streets extending outward from the city center.

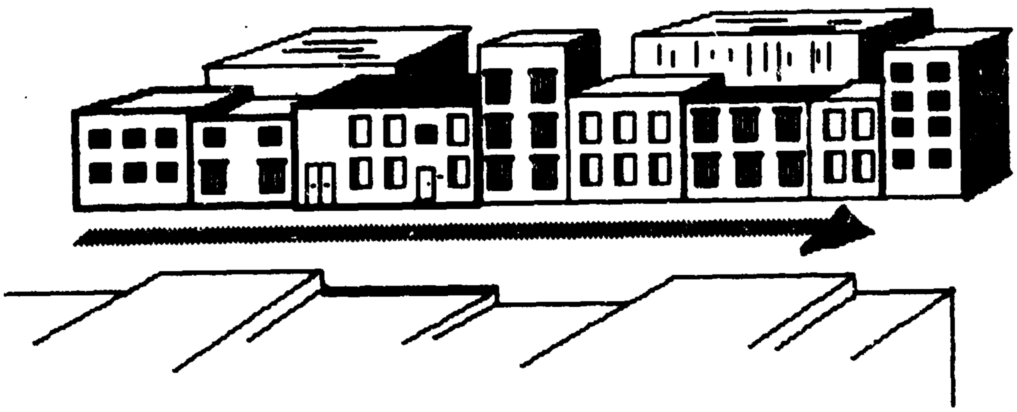


Figure 3. Urban terrain zone A3 (attached houses).

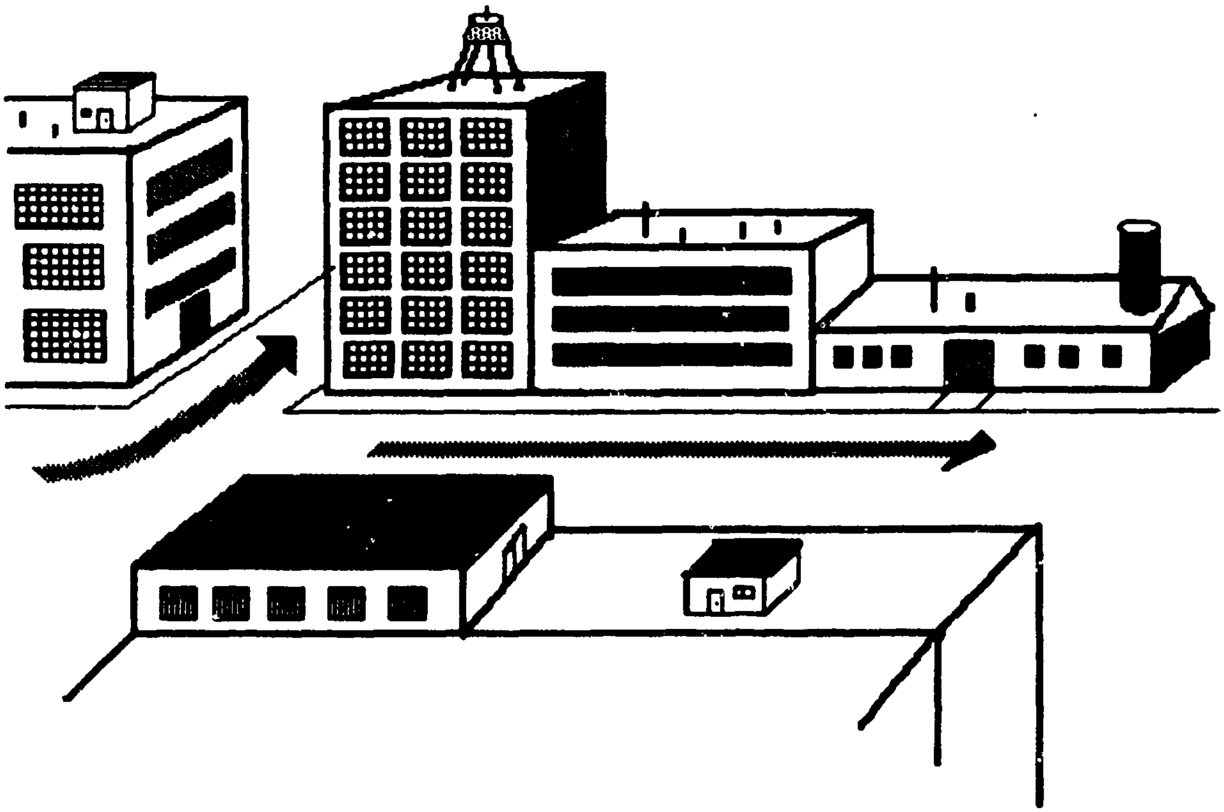


Figure 4. Urban terrain zone A4 (attached buildings, industrial/storage).

These form commercial ribbons (Figure 5) that in a peacetime situation are sites for selling consumer goods and services.

These zones form an interesting situation for military consideration because this attached character extends only one building deep. Behind the arterial faced by attached structures are areas of detached buildings. Movement of dismounted troops and vehicles along these commercial ribbons would be restricted to the street while in the detached building area behind, this restriction does not exist.

This situation exists in cities everywhere. While it is common in the U.S., it can be a dominant feature in some foreign cities, especially those that have grown rapidly in recent years. Tel Aviv, Israel, and Bangkok, Thailand are good examples.

Old Core Vestigial (Class A9). This is a zone (Figure 6) that, although not found in all cities, could have special significance to military operations where it does occur. Such zones are preserved as "old cities." A famous example is the Old City of Jerusalem. They are also common in many European cities. All are valued as cultural heritages and all have a high commercial value for their attraction as tourist sights.

They all share the common characteristics of having been built for pedestrians and not vehicles and thus have very narrow, twisting streets. In addition, buildings are low-rise, multistory structures occupying virtually all surface space. About the only open spaces (and these are small) are around public buildings, a church, for example.

As expected, lines of sight are extremely short in all directions. Ranges of engagement would also be short; minimum arming distances on certain munitions would be a problem. At the same time, the large number of mass buildings (both stone and brick) would provide a high degree of cover. Concealment would also be high.

Zones with Detached Buildings (Close-Set)

In the following subclasses, the letter c indicates that buildings, while detached from each other, are set fairly close to each other (from a few meters to tens of meters).

Core Area, Light-Clad (Class Dc1). This zone (Figure 7), has become very familiar in core areas of modern cities. The showy sky-scrapers are of glass-cladded (and other lightweight) material. Such zones are common not only in the U.S. but in Europe, Asia, Latin America, and elsewhere. One of the world's best examples is Hong Kong.

Unlike the core area already described (Class A1), the buildings in this zone are usually set some tens-of-meters apart from each other; the high value of the land is offset by the great height of the buildings. The open space in between buildings is usually in the form of small, landscaped courts and parks.

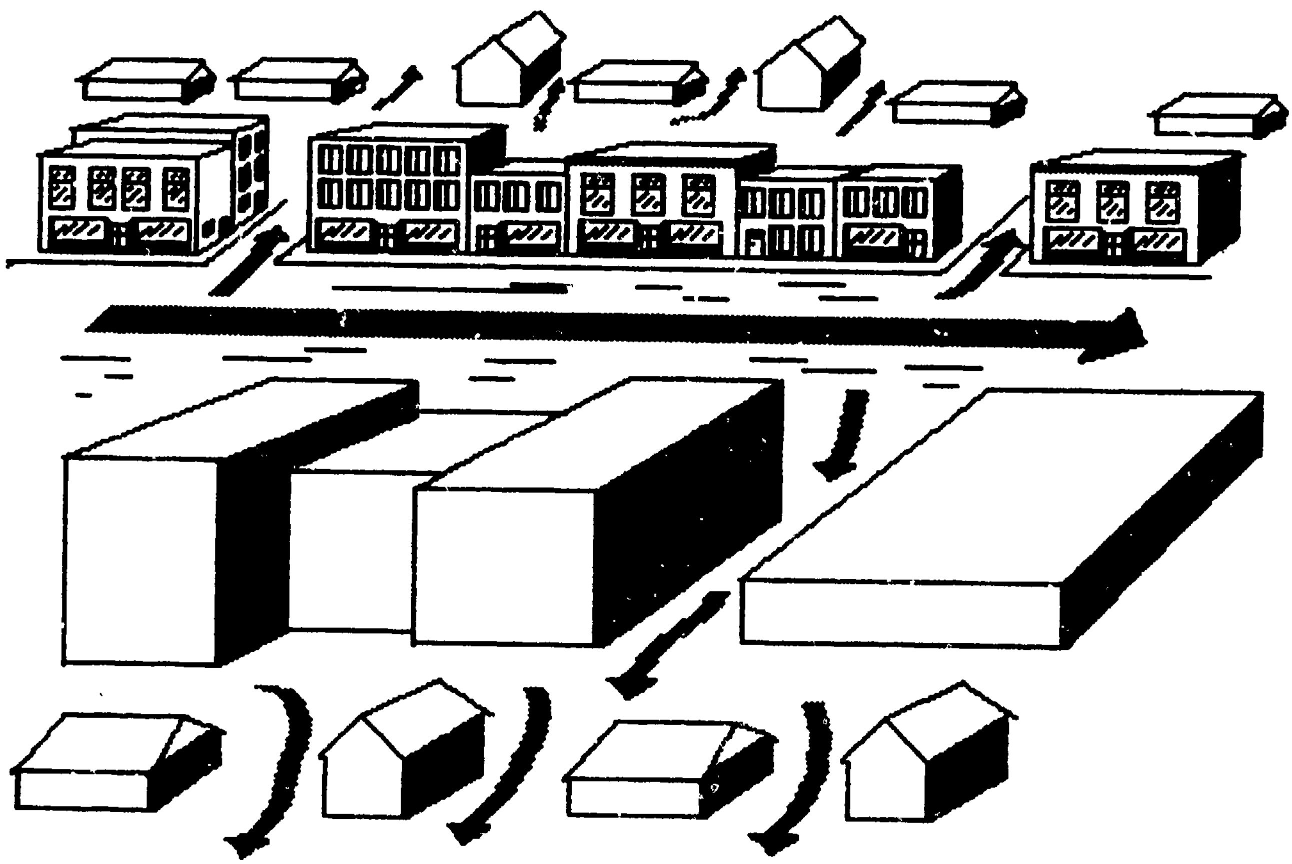


Figure 5. Urban terrain zone A5 (old commercial ribbons).

Figure 6. Urban terrain zone A9 (old core, vestigial).

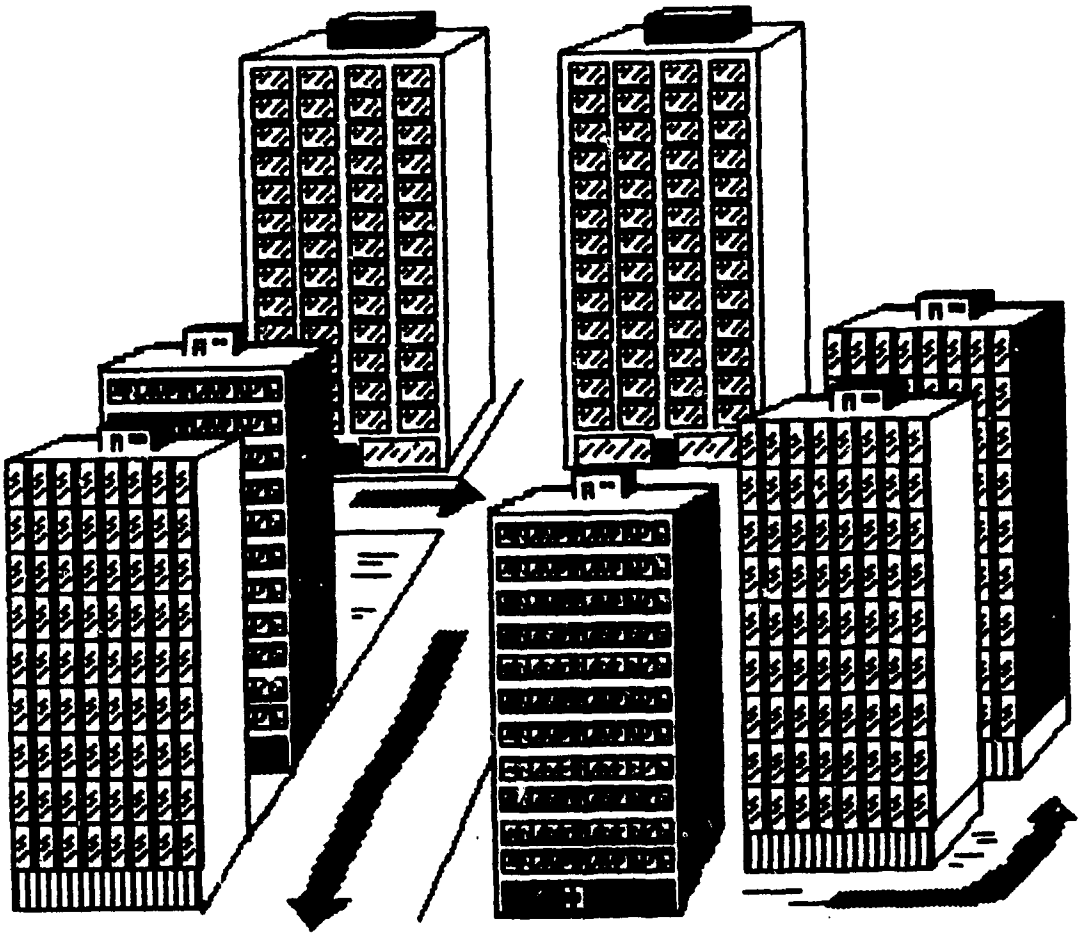


Figure 7. Urban terrain zone Dc1 (redeveloped core area).

Most of the buildings in the zone are offices. Common are headquarters for important national-level corporations and banks. Key government offices are also often present. Following the modern style of office construction, "open bay" interiors are common. Little cover is available but "back-blast" weapons could be safely fired. Another advantage of these buildings is the presence of basements and underground parking facilities.

Apartments/Row Houses, Greater Than 75% Frontage (Class Dc2). This zone (Figure 8) has buildings like those of Class A3 except that instead of being attached they are separated from each other by a short distance. Accordingly, not all pedestrian and vehicle movement needs to be confined to the street. Openings between buildings, however, are narrow, often not much more than 4 meters.

Houses, Greater than 75% Frontage (Class Dc3). Structures in this zone (Figure 9) are usually single-family houses. The aggregate area of the zones is usually large, depending on the popularity of the building of detached housing in the country where found. Many housing tracts in U.S. cities would fall in this class.

The buildings are small and contruction is usually relatively lightweight. Cover is, accordingly, also fairly limited. Rooms are small and the possibility of firing heavy weapons from the buildings is limited.

Industrial/Storage, Truck, Dock-Related (Class Dc4). This zone (Figure 10) is quite unlike the previous industrial/storage zone described. Instead of having structures fully occupying the blocks on which they sit, buildings in this zone are long and narrow in shape to accommodate the type of transportation involved. Buildings associated with railroad tracks and sidings are often separated by just the width of a railroad track. That space is easily masked by the structures, even from oblique aerial observation.

Most of the existing open space is found near the ends of buildings where industrial raw materials and finished products are stored. Only here are lines of sight reasonably long.

"Outer City" (Class Dc5). The term "outer city" refers to zones (Figure 11) that have all the physical characteristics of zone Dc1. That is, the buildings are multiple story, framed light-clad structures that are detached from each other. Outer city zones have been built, in recent years, in locations away from the city core as centers for offices and other businesses. Examples are seen at the edge of large cities in many countries.

Unlike the Dc1 zones, these outer city areas stand out sharply from surrounding suburban zones (with their low buildings) thus giving them "urban high ground" characteristics. Observation is good outward for long distances. Fields of fire and lines of sight are usually long. The zone's exposed position, however, also means that it is potentially highly vulnerable to artillery and air attack.

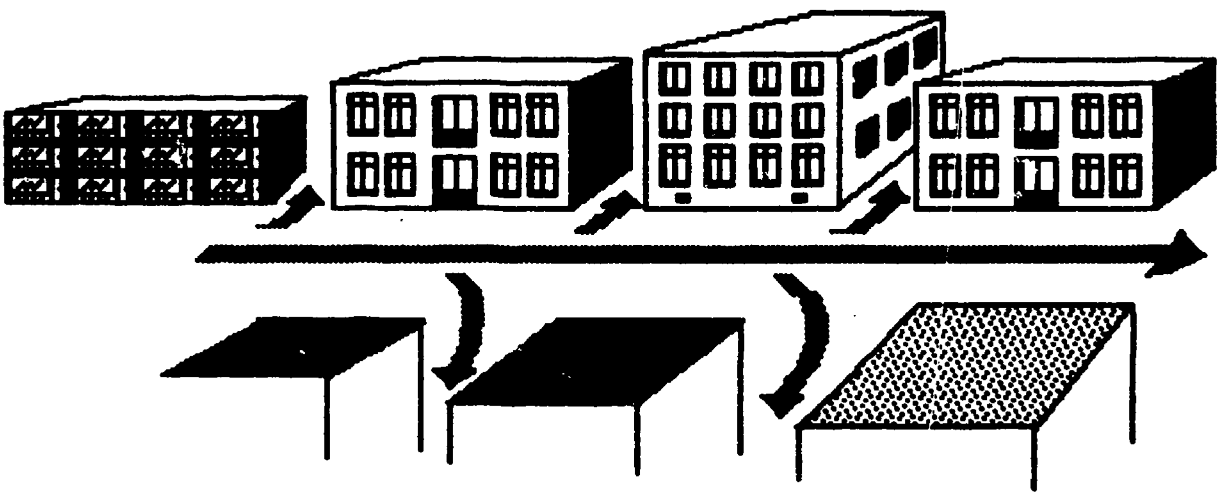


Figure 8. Urban terrain zone Dc2 (apartments, close-set).

Figure 9. Urban terrain zone Dc3 (detached, close-set houses).

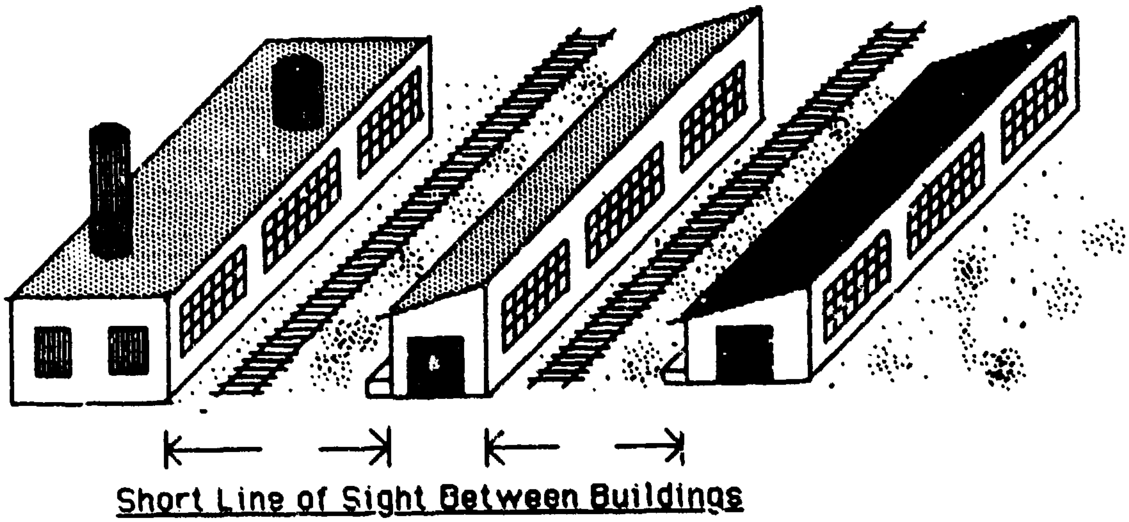


Figure 10. Urban terrain zone Dc4 (rail/dock-related, industrial/storage).

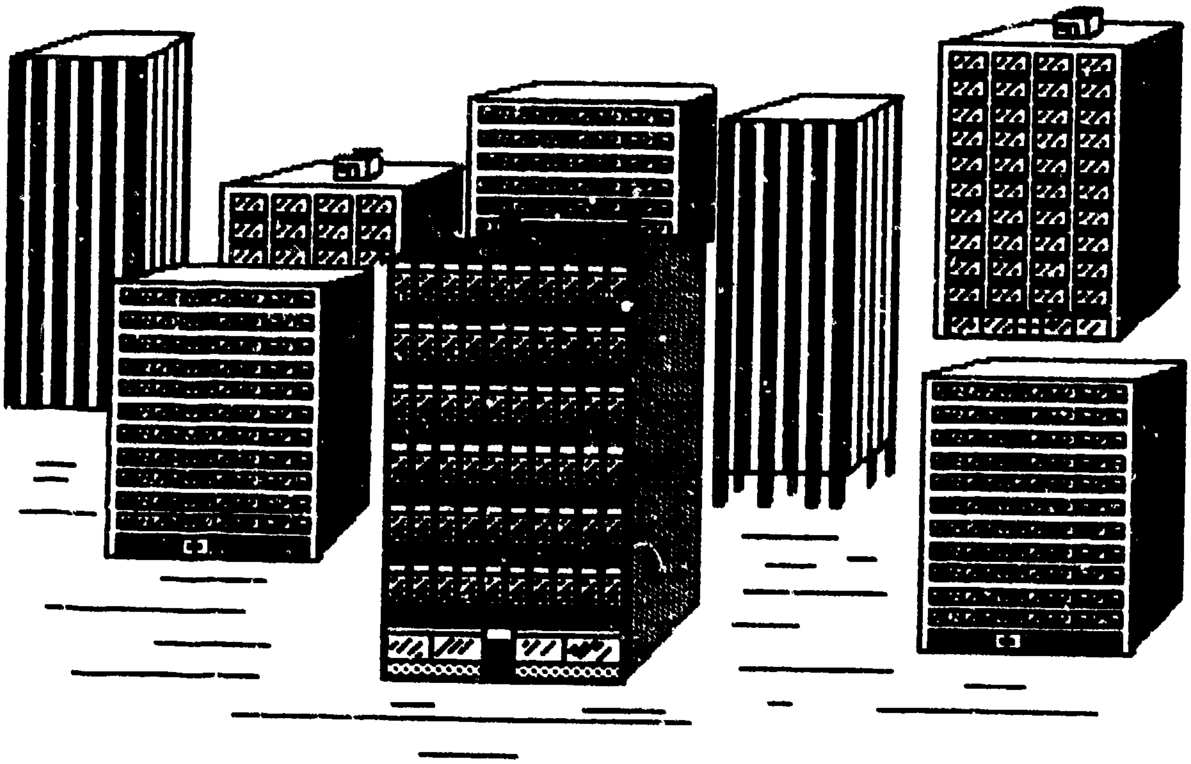


Figure 11. Urban terrain zone Dc5 (outer city).

Engulfed Agricultural Villages (Class Dc7). Rapidly expanding cities, in countries almost everywhere, have engulfed nearby agricultural villages (Figure 12) and other small towns, bringing them into the greater, or extended metropolitan area. The villages have houses and barns (which have often been converted into housing or commercial buildings). Streets are usually narrow and twisting and contrast with the broader streets and the planned, ordered look of the suburban development surrounding them.

The zones are of interest to MOUT planners because they form localized areas of high building concentrations--with short lines of sight and ranges of engagement--within areas of low building density. These nucleated village areas could form defensive strongpoints within broad areas of generally simple urban terrain.

Shanty Towns (Class Dc8). Areas of lean-to structures (Figure 13) have been built on unoccupied, low-value land in and around many cities in underdeveloped countries to serve as housing for people moving to the city from the country. The structures are made of any scrap material available: lumber, brick, sheet metal, cloth, palm fronds, etc. Cover available is thus very low. Concealment is usually quite good though because of the high density of the structures. Another problem is orientation and navigation within the zone as a result of the irregularity of building placements and the connecting path (proper streets are uncommon).

Zones with Detached Building (Open-Set)

In the following subclasses, the letter code o indicates that buildings are detached but have more separation from each other than in the previous group of close-set structures. Separations are often 200 to 300 meters.

Shopping Centers (Class Do1). Buildings in this zone Figure 14) are used mostly for commercial purposes and are set in clusters designed to favor automobile transportation (easy access from street and highways and with large, open parking areas). Buildings are designed to have large areas of unrestricted, unpartitioned interiors.

Cover is fair to good because many buildings are of mass construction and thus have strong walls. Stout, concrete-framed parking garages are also often present. Because of the large parking lots, lines of sight and ranges of engagement are long (in going outward from the cluster of buildings).

Apartments/Row Houses, Less than 75% Frontage (Class Do2). This zone (Figure 15) differs from the similar class in the previous section (Class Dc2) in that buildings are farther apart and are often set in a uniform pattern within a planned project; when viewed from the street, the open spaces between structures are wide enough to form more than a quarter of the frontage of buildings along a block (or its equivalent). These openings thus range from 5 to 75 meters or more. The general impression

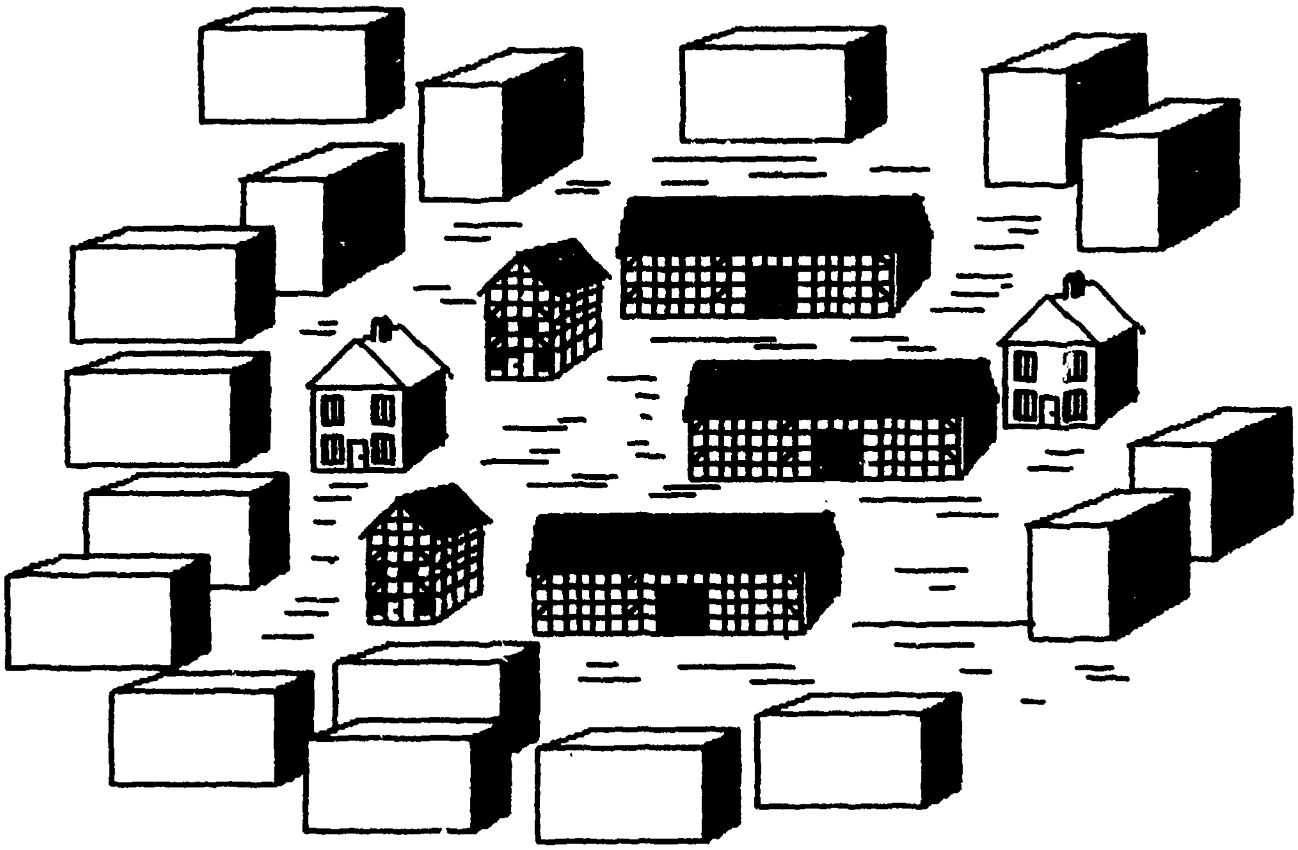


Figure 12. Urban terrain zone Dc7 (engulfed agricultural village).

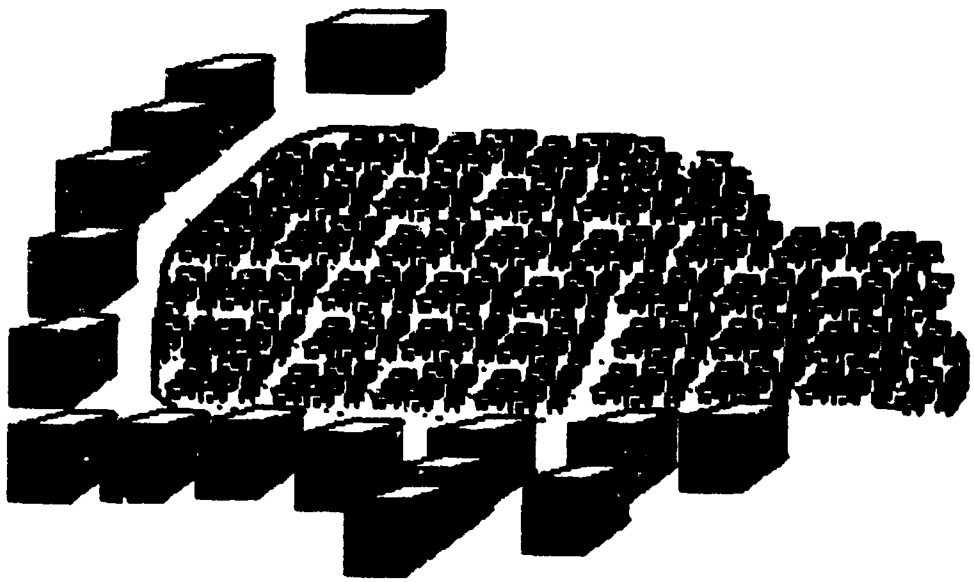


Figure 13. Urban terrain zone Dc8 (shanty town).

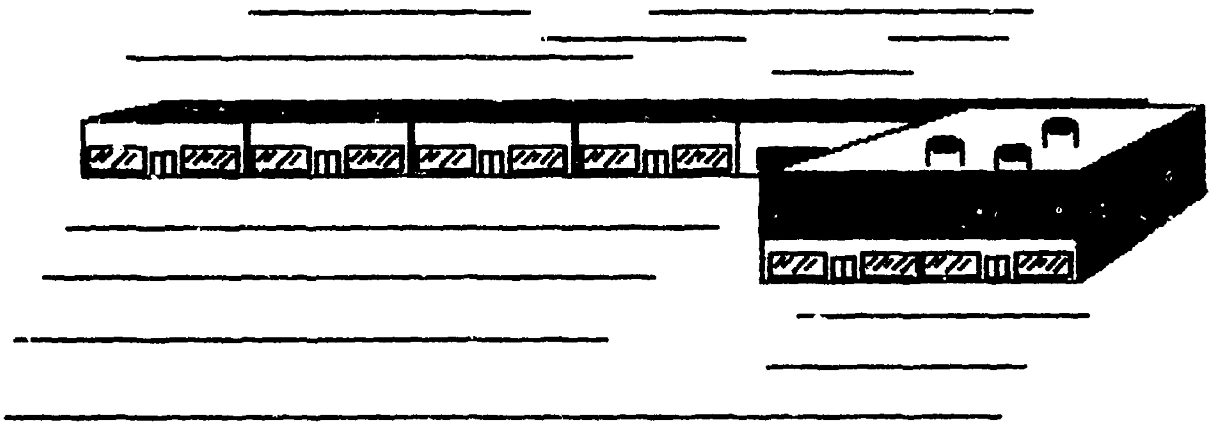


Figure 14. Urban terrain zone Dol (shopping center).

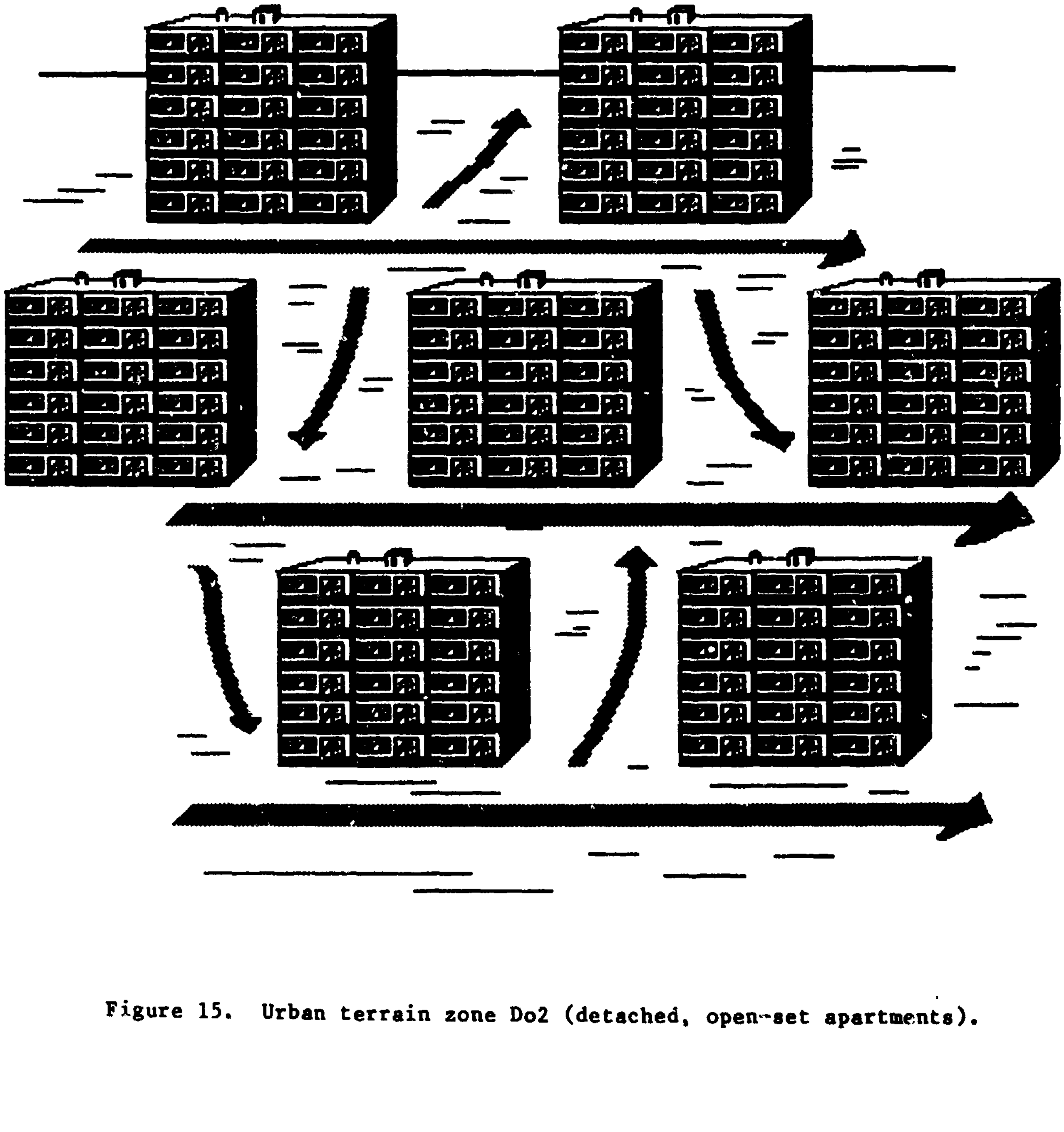


Figure 15. Urban terrain zone Do2 (detached, open-set apartments).

is one of openness. Movement in and around these buildings can therefore be in all directions. The only barriers to surface movement are light in weight, such as hedges and fences.

The amount of cover can vary in accordance with the type of construction. Some of these areas favor light-clad framed structures while others have brick or box-wall principle buildings.

Houses, Less Than 75% Frontage (Class Do3). This zone (Figure 16) is a very common one covering typical suburban subdivisions. Houses are set back from the street and separated by 5 meters or more from their neighbors on each side. These gaps are wide enough to allow vehicles to go between houses and operate in backyards.

Cover is slight with such small buildings. Maximum wall thicknesses are about 30 cm for brick or block and brick buildings. Wood framed structures, where seen, provide less cover.

Industrial/Storage, Truck-related (Class Do4). This industrial/storage class (Figure 17) is different from the previous two in having widely separated buildings. The sparse pattern of buildings in this zone, designed to provide sufficient space for service by trucks, has wide streets within the zone and extensive parking lots. In addition, open space around the buildings serves as outdoor storage for goods and raw materials.

Lines of sight within the zone are fairly long. Heavily constructed buildings, often concrete or heavy masonry, provide cover. Also the buildings are normally designed to permit vehicle entry; floors are usually strong enough to support heavy vehicles.

As with all buildings, roofs offer little resistance to incoming munitions. Coupled with the low degrees of masking, the zone would be particularly vulnerable to air attack.

Commercial ribbon (Class Do5). This zone (Figure 18) consists of large, one or two story buildings or groups of buildings fronting a major arterial street. They have open spaces in between and large parking lots. Mass construction is common and thus cover possibilities are good.

Lines of sight from the buildings to the street are long, thanks to a deep setback and location along wide streets. These arterial streets are important to the traffic flow within a city. As such, they often lead to or from key features, such as bridges or major intersections.

Administrative/Cultural (Class Do6). These zones (Figure 19) are made up of clusters of buildings that were constructed according to a master plan that specified a considerable separation from one building to another. This type of plan is used both to allow buildings to be viewed from all sides (as in a cluster of class-styled government buildings) or for efficiency (as on a college campus or a military reservation).

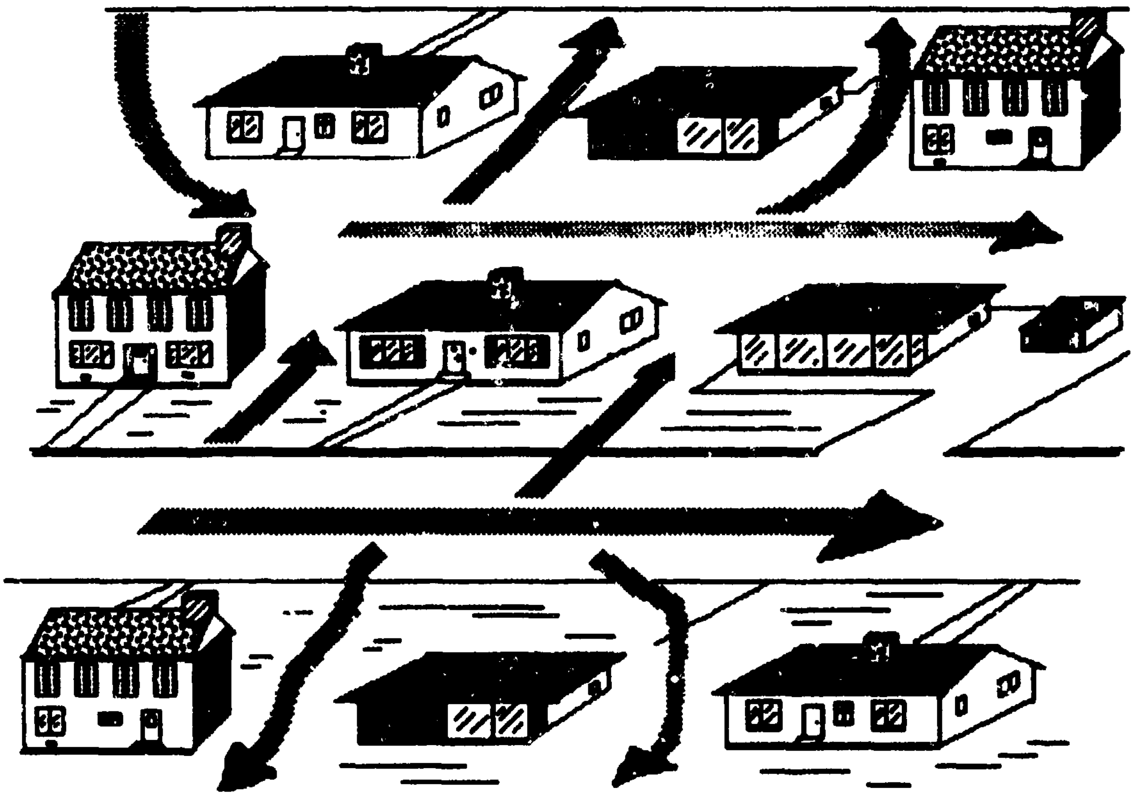


Figure 16. Urban terrain zone Do3 (detached, open-set houses).

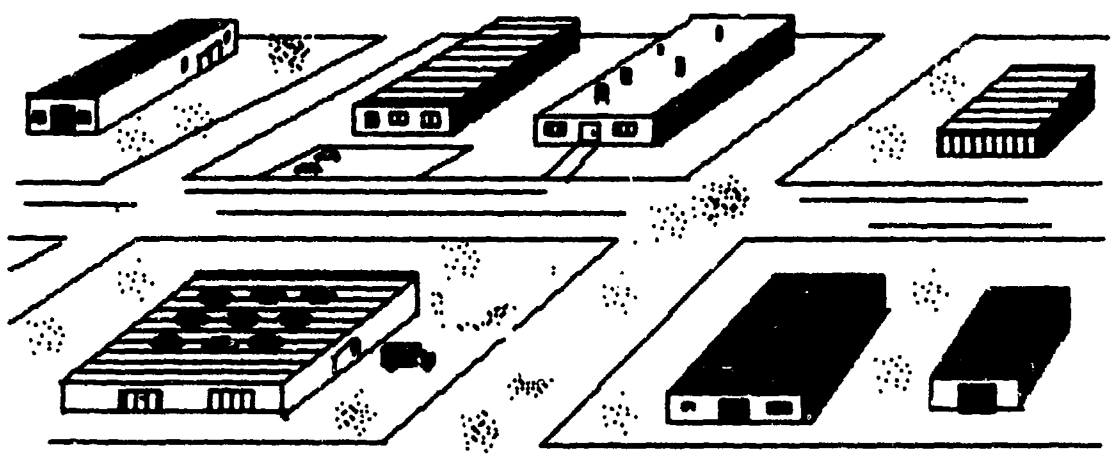


Figure 17. Urban terrain zone Do4 (detached buildings, industrial/storage).

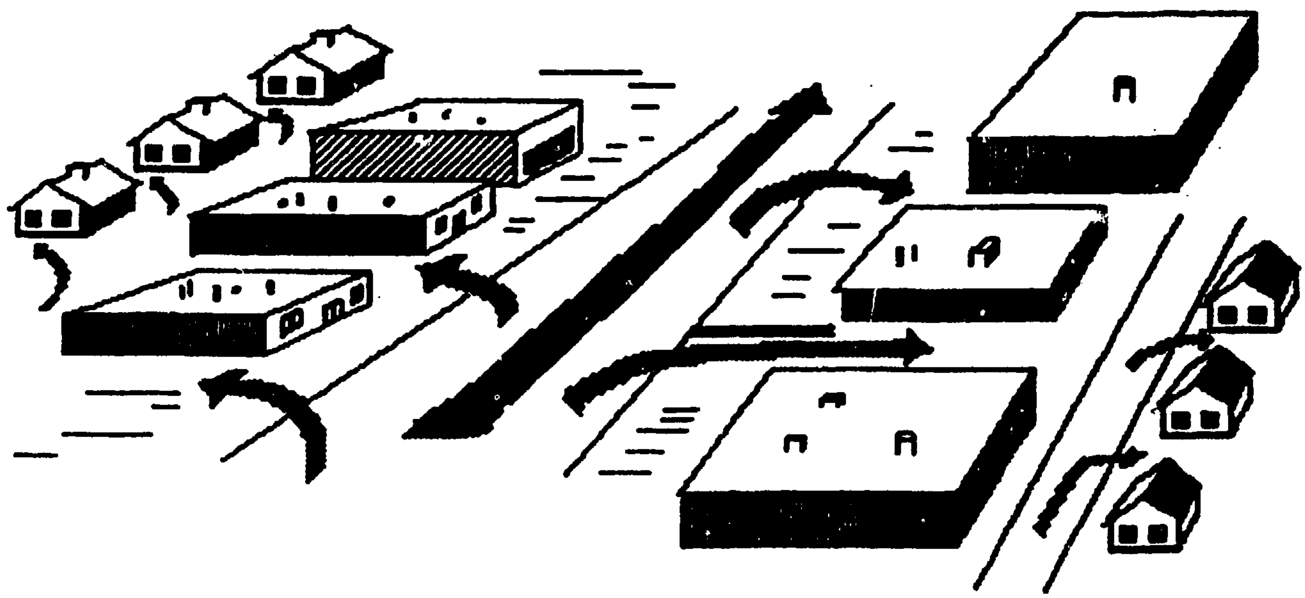


Figure 18. Urban terrain zone Do5 (new commercial ribbons).

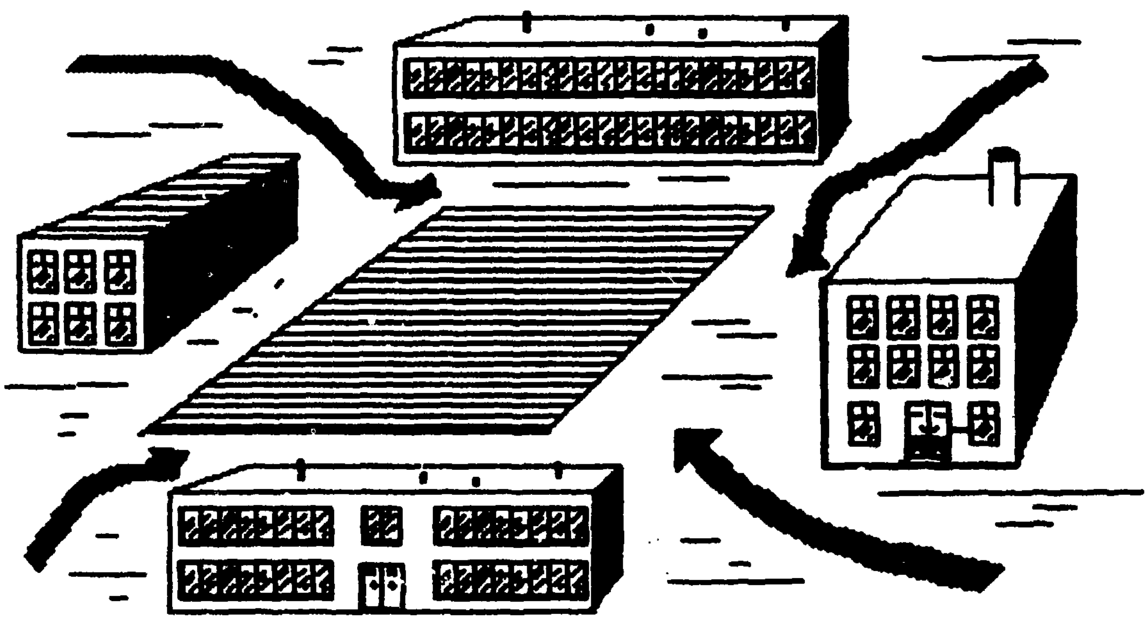


Figure 19. Urban terrain zone Do6 (administrative/cultural).

Buildings are often stoutly made thus offering a fair degree of cover. Lines of sight and fields of engagement with the zone are long.

Although morphology is emphasized in the classification system, the functional aspects have order. In Table 2, the three subdivisions of Class 1 are all commercial: the city core has two separate areas, attached and detached (close-set) while shopping centers are detached (open-set). Class 2 provided for different morphological patterns of apartments. Class 3 comprises small apartment houses and freestanding houses. Class 4 has three morphological variations on the industrial/storage type. Class 5 refers to commercial areas located beyond the core. Class 6 is exclusively administrative-cultural (found throughout the city). Class 7 provides for urban-related agricultural villages. Class 8 covers shanty towns. Class 9 makes allowance for the historic of old central core areas.

The Study Cities

The area examined for each city was the continuously built-up area. Some of these areas involved more than a single corporate entity (this fact is recorded by the use of dual names for some of the cities: Tel Aviv-Yafo; Athens-Piraeus; and Panama City-Balboa). The process of interpreting the terrain zones was started in the center of the city and proceeded outward until a break with the rural territory surrounding was reached. Outliers were excluded when they were observed to be more than a kilometer away from the main contiguously built-up area. In a few instances, the lack of either map or photo image coverage of distant outlying areas caused them to be excluded. In a few other instances, where advancing suburbanization from another urban center was encountered, an artibrary halting line was selected. Another problem was faced in selecting the amount of nonbuilt-upon space to be included. The general rule was followed that if the open (often agricultural land) lying among urbanized units was connected with the surrounding countryside it was assigned no urban class and was marked with an X on the maps.

The potential problem that derives simply from size and significance of urban areas--and especially from country to country--was mitigated by selecting cities that are reasonably close to the same size in population. Many are capital cities, but this is only incidential considering that in the developing countries included in the study, these cities are the only [illegible] of any significance. Areas ranged from 30 square kilometers to 400 square kilometers (see Figure 20). The assumption was made that dealing with the corporate city alone was of little value. (Owing to the vagaries of the political world, commonly the principal corporate city of a metropolitan area comprises only a part and only occasionally does a corporate city exceed the built-up area).

Table 2

Urban Terrain Zones
Function/Morphology Relationship

Basic Class Number	Dominant Function	A (Attached)	Primary Function Dc (Detached Close-Set)	Do (Detached Open-Set)
1	Commercial and offices	Commercial core	Commercial core	Shopping centers
2	Residential	Apartments near core	Apartments and row houses	Apartments
3	Residential	Low-rise apartments	Houses, close-set	Houses, open-set
4	Industrial/ storage	Flush to street	Railroad and dock-related	Truck related
5	Commercial	Old commercial ribbon	Outer city cluster	New commercial ribbon
6	Administrative/cultural	---	---	Open, planned
7	Residential and barns	---	Old villages	---
8	Temporary residential	---	"Shanty towns"	---
9	Commercial and residential	Old commercial core	---	---

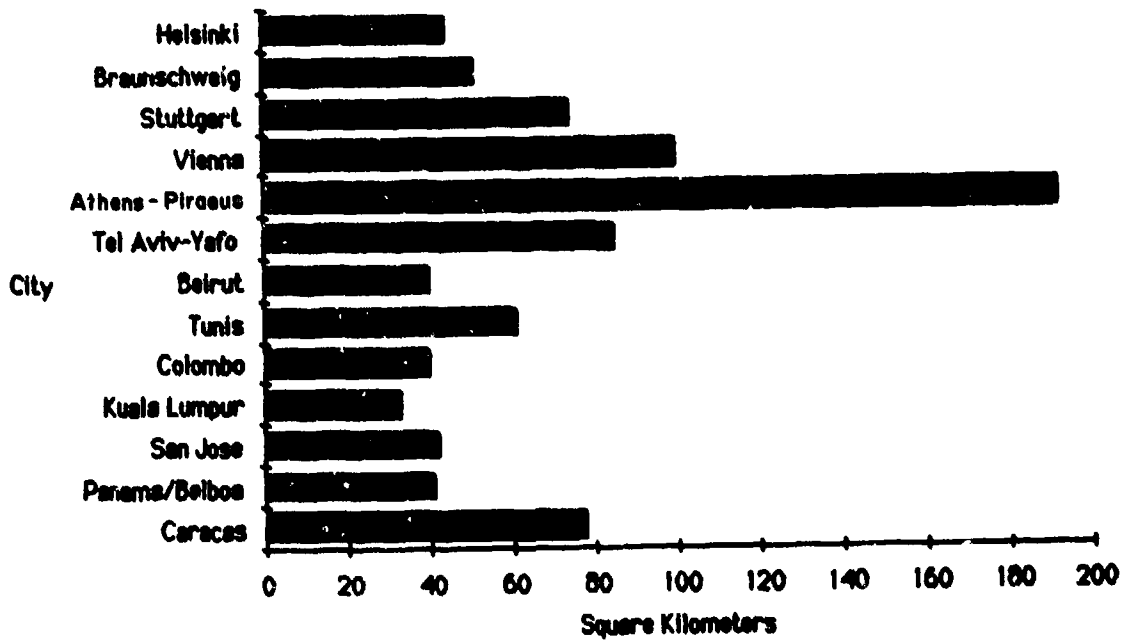


Figure 20. Cities: Area (sq km).

The selection of cities was based primarily on the desire to have a broad representation of urban terrain from various regions of the world. Accordingly, examples were drawn from Western Europe, the Mediterranean, Asia, and Latin America. Four are from the first group, four from the second, two from the third, and three from the fourth.

Field Observations and Measurements. Each study city (except Beirut) was visited to gain a more complete knowledge of its composition and characteristics and to augment the photo interpretation. The approach was systematic and uniform for all places visited.

In each city visited, traverses were made, on foot, of each type of urban terrain zone encountered. In the more intensive zones, such as the A1 core areas, a crisscross pattern of alternate streets was followed. In the large area zones, such as those of detached houses, selected streets were studied. Prior to entering the field, the remotely sensed imagery was consulted to identify these large areas. Estimated centroids of what were later--upon completion of the full image interpretation process--to be delimited as urban terrain zones were identified and marked on maps. Streets at these points were then visited.

In each zone, ground photographs were taken of representative situations and representative buildings. In addition, significant features were noted. Both were referred to in the air photo interpretation process. Full interpretation was always undertaken subsequent to the field visits in order to make maximal use of the field observations.

Six of the cities were visited during the summer of 1983 and five different cities were visited during the summer of 1984. Some cities were observed on more than one occasion. Helsinki had been studied on the ground for the 1977 study and visited again in 1983. Athens was visited both in 1983 and 1984. San Jose, Costa Rica was studied on several occasions during the late 1970s and early 1980s. Colombo was revisited after a period of some 25 years. Vienna had also been observed some 15 years before. Braunschweig, visited in 1982 in conjunction with an intensive study and model building of an adjacent area by TRASANA, was revisited and studied intensively in 1983.

In addition to observation, photographing and field notation, a series of sample field measurements was made of characteristics of buildings. Measured, in particular, were building construction types, building heights, and exterior wall surface textures. Detailed information was gathered for the A1 (core) areas of all cities (with the exception of Beirut) and generally for all terrain zones. Field observation was employed because of the great variety of structures and other characteristics found and to gain information where masking by tall buildings precluded identifications from aerial photography.

The method used for all A1 areas consisted of selecting sample streets from within the zones to be studied. These streets, deemed from field observation to be representative, included both principal thoroughfares and lesser streets. Notation was made first of buildings on

one side of the street for several blocks (the observation being made from the opposite side of the street) and then of the other side of the street by reversing the direction of the traverse. Each building's height was recorded under headings of building types. A separate inventory examined surface textures and <u>building</u> material. To keep the concept of a <u>building</u> uniform and to offset the vagaries of size, some typical buildings were first measured (by pacing the frontages) and these were used as standards. Thus, two or three small buildings, in some instances, were only the equivalent of one of the control buildings. Without such a procedure, large buildings would have been underrepresented.

In addition to the buildings, nonsystematic observations were made on such features as street widths, presence of underground features, and the character of rooftops.

BACKGROUND ON WORLD URBAN MORPHOLOGY

Prior to discussion of findings, general reasons explaining differences and similarities among cities should be reviewed. This is especially important when comparing international cities that are within countries of varying levels of economic development and possessing varying forms of government. The following relates and discusses universal factors that affect the morphology of cities. They are

- History of growth, expansion
- Current level of economic development
- Cultural/political factors
- Municipal statutes and ordinances
- Physical site

History of Growth, Expansion

The amount of growth and expansion that has occurred in a city and the period of time in which it has occurred are important to know in understanding and interpreting the measurements of area within each urban terrain zone. Cities that have had most of their a real expansion in recent years will have considerably higher proportions of their total area in modern (usually more open) types of areas and with more modern types of construction than will cities that were areally large before the modern period of expansion and whose newer extension form a somewhat smaller proportion of their total areas.

The reasons for relative differences in areal expansion vary. Some is the result of such politically motivated occurrences as being the principal urban center for a new country, one which did not gain political independence until the post-World War II period. At the opposite end of the

spectrum are the older cities of countries--especially those in Europe--whose political status has been stable for some time. Specific cases representing both types as well as intermediates in this study are

- Tel Aviv is a city whose real expansion has taken place almost entirely since independence of Israel in 1948 and continues to grow in space today. The area built in the last 35 years dwarfs old Yafo (an urban place of antiquity) and the area of Jewish settlements built adjacent to it in the period between the end of World War I and Independence. The city has, in fact grown so fast that there is no traditional core area; a common string street has been forced to serve this function.

- Caracas is another city exhibiting very rapid peripheral growth in recent years. Not until 1938 were restrictions to the expansion of the city lifted. It then grew so rapidly that the basic infrastructure of streets, utilities, and other amenities could not be provided everywhere and immigrants seeking housing of any type "squatted" in large areas of poorly built structures on the surrounding steep hillsides.

- The German cities of Braunschweig and Stuttgart, as is true of most war-damaged cities in that country, elected to remodel the core area as they rebuilt them but in addition, have allowed controlled growth at the periphery.

Current Level of Economic Development

While most cities in countries around the world have exhibited a tremendous growth and expansion within the last 30 years and especially in the last 20, the impetus to grow is largely a function of the level of economic activity in the countries in which they are a part. Accordingly, in these study cities there are examples of continuous and rapid expansion and examples of lesser levels of activity. Some of these areas are

- Caracas, as the center of mineral-rich Venezuela, furnishes the demand for offices to serve as financial centers for the country. Housing and services have followed.

- Kuala Lumpur, as the center for resource and agriculturally rich Malaysia, has also become the center for the country's finances. Moreover, it has sought to fill the vacuum created when Singapore, the de facto financial center of the whole Malay Peninsula, became the center for its own city-state country when it was created in 1965.

- Colombo, on the other hand, is the center for a country (Sri Lanka) that has not shared much of the recent general economic development of the rest of the world. As a result, Colombo is little changed from pre-Independence days.

Cultural/Political Factors

As might be expected, cities reflect the culture of the people of the country to which they belong to a considerable degree. Longstanding practices in architectural style are found to have physical manifestations in urban communities of all sizes within countries. Sometimes these cause significant differences in the urban pattern presented. In others, the result is little more than cosmetic. Some examples follow:

- In German cities the curious practice of placing pitched roofs on modern reinforced concrete framed buildings has been retained in immediate postwar and current development. Reflected in this practice is the concern for maintaining the traditional culture, one that dates back to the Middle Ages and before when cities, figuratively speaking, grew out of the forests. The practice of favoring pitched roofs is violated in high-rise structures but is widely seen in low-rise buildings in all core areas.

- In Mediterranean areas (those on the continent of Europe, in the Middle East and in North Africa), cultural tradition calls for the use of urban form, that is, the filling of building lots so that there is no space laterally between building and little or no open space to the front or back. While this practice is one followed out of necessity in core areas of cities everywhere because of expensive land, in Mediterranean and Mediterranean-influenced parts of the world it extends, for cultural reasons, to residential as well. As a result, houses are crowded together even in new suburbs at the edge of the city. The phenomenon is seen in Athens, Beirut, Tel Aviv, and Tunis in the Old World and in its colonial form in Latin America as well.

Municipal Statutes and Ordinances

Not only are there some broad differences among countries but the layer of municipal governments can cause some variations from the norm as well. The study cities demonstrate some of these.

- Panama City, during the long period the U.S. leased the Canal Zone, was not allowed, as an entity, to encroach upon the adjacent Canal Zone. As a result, an extremely strong contrast in form is seen along the two sides of the former boundary. Urban areas in the Zone (in Balboa) are orderly and planned with wide spacing between structures. By contrast, the older parts of Panama City directly adjacent are densely set. In addition to the city being proscribed from crossing the boundary, these structures, being in the oldest part of the city, reflect typical Latin, Mediterranean-derived "urban form" modes of building placement on their lots. Newer parts of Panama City, themselves represent modern urban planning practice and thus manifest a pattern little different from forms seen in the Canal Zone.

- Many German cities provide for their citizens public land to maintain gardens and construct small weekend huts. These Gardenplatzen occupy large enough areas of land to require a separate Level III urban terrain zone class.

● The sharpness of the edge of the city is also a function of laws and ordinances. German cities, in particular, tightly control urban expansion. The surface manifestation is the presence of sharp boundaries between city and rural land. By contrast, little or no control is exhibited in Caracas and Tunis where sprawl extends out into the mountains in the first instance and the desert in the latter.

Physical Site

Physical site is placed last among this brief list of causes for differences because its effects are readily obvious. The concern in this study centers largely on whether the site is restrictive to urban expansion or permits it. For example,

● Tel Aviv's growth has been continually to the north and to the east from its original development core near Yafo. Expansion has been virtually unrestricted as it has marched out into desert lands although it has now reached a point where it is competing with rich agricultural land. Other cities with little or no physical restriction to expansion are Panama City, San Jose, Stuttgart, Braunschweig, Helsinki (to the landward side), Kuala Lumpur, Colombo, and Tunis.

● Caracas, by contrast, is a clear case of being restricted in the lowland and foothills between two paralleling east-west ranges of the Andes. Athens and Beirut are in a somewhat similar position occupying as they do, land on a narrow coastal plain (and a valley coming into that plain in the case of Athens).

EVOLUTION OF BUILDING CONSTRUCTION METHODS

A major change in building construction method, taking place in cities throughout the world during the last 50 years, has been the conversion from heavy reliance on mass construction to that of framed construction. This process, which began with the introduction of frames for large buildings in the 1890s has not proceeded to the point where virtually all new construction of buildings of any appreciable height--certain three stories and beyond--and breadth are now made with frames. Frame materials are either steel griders or steel-reinforced concrete columns and beams. In both cases, the wall "in-fill" material placed within the frame or a "skin" placed outside of the frame is very light in weight and is not load-bearing.

Accordingly, there are, in cities all over the world, remnant, older masonry structures existing alongside newer framed construction buildings. In rapidly growing cities, these framed structures are found both in central areas where they are replacing the older masonry structures and at the periphery of cities where rural land is being converted to urban usages. This is not to overlook recent mass construction buildings seen in many industrial/storage urban terrain zones and some commercial terrain zones.

This conversion has many manifestations of significance. In general, the framed structures--inherently capable of being much taller--are the modern skyscrapers of the day and are used primarily for offices, hotels, and apartments. Clearly, these are instrumental in changing the very shape and profile of cities.

Most importantly, for the purposes of this report, this conversion process has created (and is creating) an urban terrain with characteristics markedly different from those of the past. Understanding this new character is vital in MOUT considerations. The city of today is far different from the city of World War II days. Then, masonry buildings predominated. They provide considerably more cover than do framed buildings because of their vastly thicker walls. Wall breaching, a matter of concern with masonry buildings, is virtually a moot point with framed structures. Almost all munitions are capable of penetrating most of the walls of framed structures--although the effectiveness of rounds (especially small arms fire) penetrating these thin walls is not fully known.

An accompanying feature of framed buildings is that many of them are quite tall (the frame being well-suited to such construction). Tall buildings become at once both good places for observation and targets that are not only larger but ones that may be hit readily by aircraft-carried weapons and artillery. Also, these large framed buildings will often (depending on their functional usage) have large rooms allowing for a variety of military uses not possible in the older masonry buildings with their characteristically smaller rooms.

The Perspective of International Cities

Certain variations on the general theme are observed in the study cities. Some cities are farther along the conversion process than others. Some are essentially new cities in which most of the construction has occurred since the framed construction revolution began and framed buildings became the dominant type. Others are older cities that had achieved large areas of masonry structures before the advent of framed structures and still retain a high percentage of masonry structures.

The amount of economic development (of the country in which a city is found) during the last 50 years plays a significant role in understanding the patterns observed in cities. Until fairly recently, cities in underdeveloped countries in most parts of the world made extensive use of masonry construction. The building material (for the making of bricks mainly) was local and the labor of erecting buildings with this unit masonry material was affordable. The use of frames would have required the importing of structural steel and cement. In recent times, however, cement factories and steel plants were established (or these materials could be imported economically from other low-cost sources). Other technological advances favoring the move toward framed construction have been the widespread introduction of the movable and portable construction crane and the ability to transport pre-mixed concrete to the

construction site by truck. Coinciding with this was a need for larger structures (higher-rise) that could be built only by using framed construction methods.

The result has been a virtual elimination of mass construction for buildings of almost all types and sizes. An interesting curiosity in these countries is the use of framed construction for even small, low-rise buildings. In northwestern Europe and the U.S., by contrast, framed construction is reserved mainly for multistory structures while lower buildings still commonly employ mass construction. Common building materials are brick, concrete block, or either poured-in-place or "tilt-up" concrete construction.

Speaking specifically of the study cities, a simple distinction can be made between those cities that had achieved a significant part of their present areal size in the "mass construction" era--and accordingly have fairly high proportions of mass buildings--and those cities whose present size has come about largely in recent times. These latter cities, because of their tremendous impetus for growth, have also been ones to have replaced many of their masonry structures that were in the original core areas. Many of these masonry remnants (mainly brick) today stand incongruously small and mean alongside their new tall and shiny framed brethren.

Cities of the study with relatively large areas of masonry buildings are the four European ones (Helsinki, Braunschweig, Stuttgart, and Vienna) and the Asian city of Colombo located, as it is in an economically backward country. Also in this class is San Jose, Costa Rica, a city in a country that simply does not have the base for rapid economic growth and development. Standing in sharp contrast are those cities where urban growth has been rapid and have high proportions of framed buildings. These are Tel Aviv, Beirut, Panama City, Caracas, Kuala Lumpur, Tunis, and Athens.

More detailed discussion of the zonal pattern of this construction phenomenon is presented in later sections.

URBAN TERRAIN ZONES

Urban terrain zones have been delineated on maps of the study cities. These zones, each distinctive and representing homogeneous areas on the ground, follow the classification scheme presented above.

For each of the cities, there is a series of thematic maps, each map being devoted to but a single urban terrain class. The following example (Figure 21) is of urban terrain zone class Dc4 (industrial/storage, railroad and dock-related) for the city of Braunschweig, West Germany. The example contains a total of 19 separate, homogeneous areas of the city that meet the definition of the class. Other urban terrain zones also have representatives in several parts of each city. The use of the term zone in this report is thus somewhat extended from a simplistic one that would have but a single occurrence of a zone in a city. In Figure 21, the Dc4 zone occurrences are industrial/storage areas that are found along the railroad

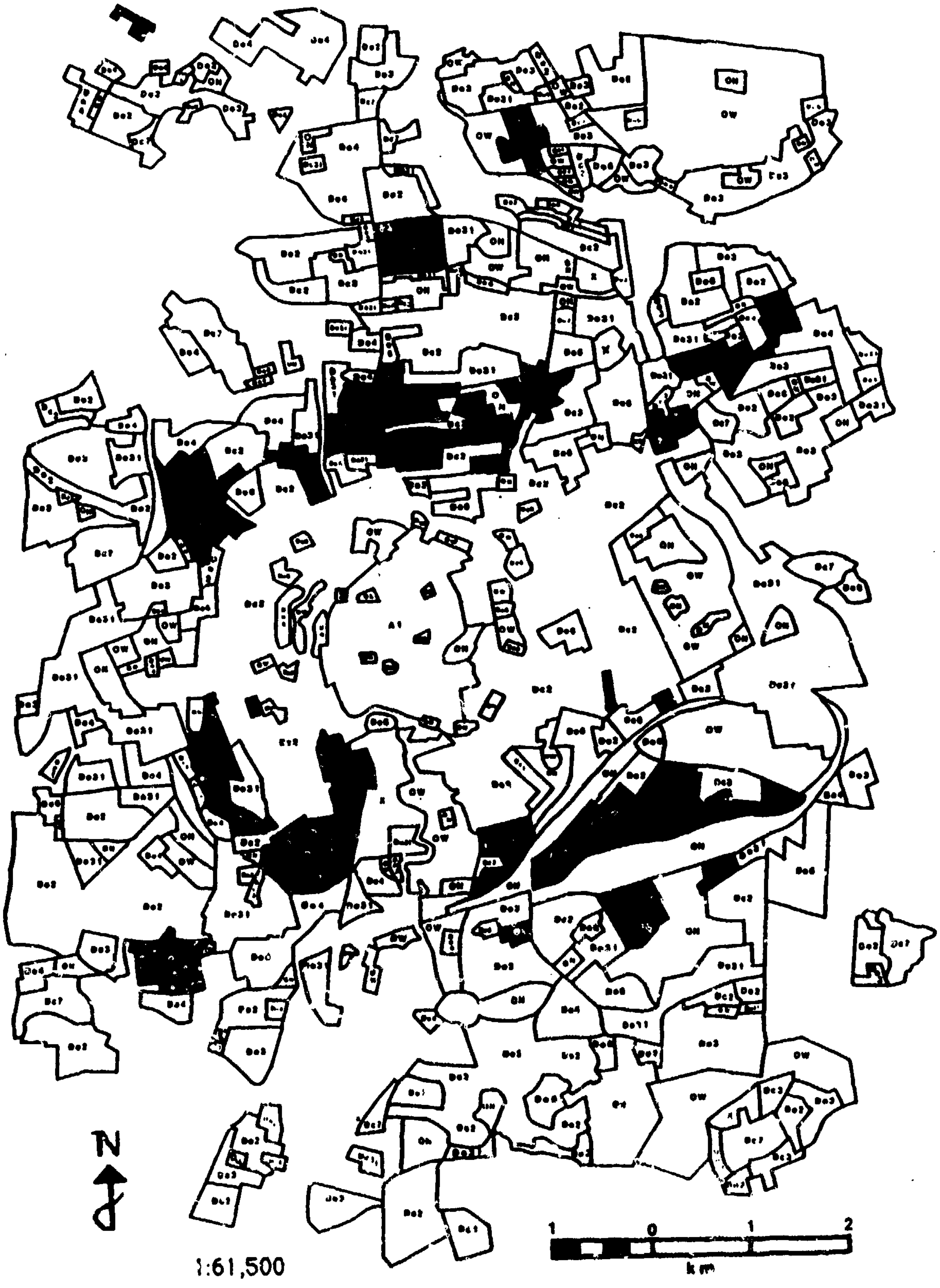


Figure 21. Braunschweig: Industrial/storage, railroad or dock-related (Dc4).

service lines in and around the city. This pattern is quite similar to that found in cities throughout the world (see a later section for visual comparison of other classes).

The Delineation Process

For each city, the visual imagery was interpreted--supported by field observation--and boundaries were drawn around each occurrence of each urban terrain zone. The boundaries were then transferred to base maps of the cities. An overlay was then prepared showing all of a city's zones. Then, each zone was given a separate thematic overlay. In this part of the process, all occurrences of a class were blackened (as is seen in the Braunschweig example).

The Measurement Process

Measurements of the area of each urban terrain zone class were then made using an electronic planimeter with the scale programmed to read in hectares (100 by 100 meters, or 10,000 square meters). Each map was then reduced to fit on standard paper. Aggregate figures were then compiled.

MEASUREMENT RESULTS

In the broadest aggregated view (Figure 22), more than two-thirds (69.6 percent) of the area of all urban terrain consists of detached buildings. Only 21.0 percent of the total area consists of terrain where buildings form a solid phalanx when viewed from the street; 9.4 percent is in open space, wooded and nonwooded. Thus, the part of the city where virtually all movement of personnel or vehicles is channeled into and restricted to the streets—the sort of environment often conjured up in grisly MOUT scenarios—forms but a fifth of the total.

For purposes of discussion, refer to the following abridged version of the urban terrain zone classification system (Table 3). Full explanation is given in Appendix A.

Areas (in hectares) and the percentages they form of the total for all urban terrain classes are given in Table 4. Cities are further grouped into the regional classes of 1) Europe 2) Mediterranean (cities within countries bordering on the Mediterranean Sea) 3) Asia and 4) Latin America.

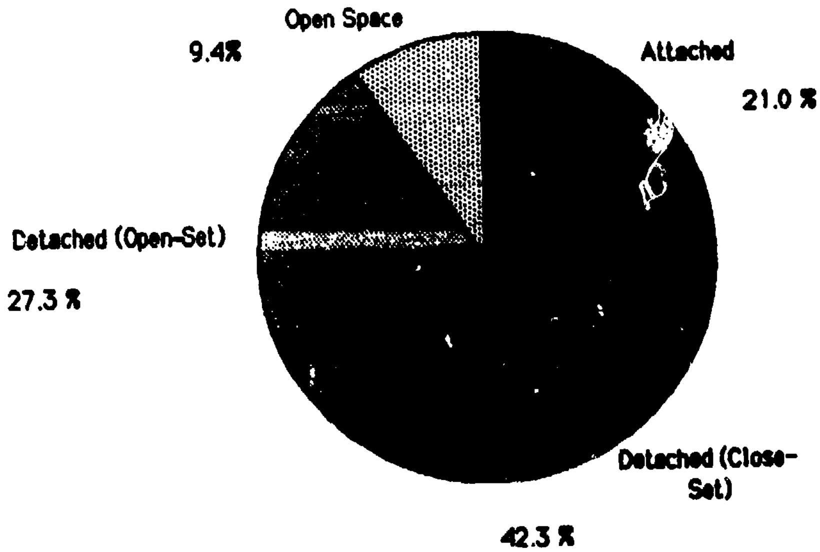


Figure 22. Urban terrain zones, major groups: Area.

Table 3

Urban Terrain Zones

A		
	A1	Core area
	A2	Apartments/hotels, core periphery
	A3	Apartments/row houses
	A4	Industrial/storage, full urban form
	A5	Old commercial ribbons
	A9	Old core, vestigial
Dc		
	Dc1	Urban redeveloped core area
	Dc2	Apartments, >75% ground coverage
	Dc3	Houses, >75% ground coverage
	Dc4	Industrial/storage, RR or dock-related
	Dc5	Outer city
	Dc7	Engulfed agricultural village
	Dc8	Shanty towns
Do		
	Do1	Shopping centers
	Do2	Apartments, <75% ground coverage
	Do3	Houses, <75% ground coverage
	Do4	Industrial/storage, truck-related
	Do5	New commercial ribbons
	Do6	Administrative cultural
ON		Open space, not built upon
OW		Open space, wooded, not built upon
Do31		A level III classification for leased garden areas (with small structures) in German and Austrian cities

Table 4

Urban Terrain Zones
Area (In Hectares) and Percent

	Urban Terrain Zones—A (Attached Buildings)											
	A1		A2		A3		A4		A5		A9	
Cities	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
EUROPE												
Helsinki	41	.9	37	.8	395	8.8	149	3.3	-	-	-	-
Braunschweig	153	3.0	-	-	-	-	-	-	-	-	-	-
Stuttgart	106	1.4	95	1.3	267	3.6	116	1.6	73	1.0	-	-
Vienna	107	1.1	247	2.5	2822	28.1	100	1.0	61	.6	-	-
Subtotal	407		378		3484		365		134			
Percent		1.5		1.4		12.7		1.3		.5		
MEDITERRANEAN												
Athens-Piraeus	99	.5	1471	7.6	6034	31.4	165	.9	-	-	-	-
Tel Aviv-Yafo	-	-	21	.2	232	2.7	137	1.6	-	-	-	-
Beirut	47	1.2	991	24.6	446	11.1	53	1.3	-	-	-	-
Tunis	54	.9	157	2.6	541	8.8	74	1.2	-	-	177	2.9
Subtotal	200		2640		7253		429		-	-	177	
Percent		.5		7.0		19.1		1.1		-		.5
ASIA												
Colombo	57	1.4	-	-	225	5.6	63	1.6	28	.7	-	-
Kuala Lumpur	37	1.1	33	1.0	10	.3	-	-	89	2.7	-	-
Subtotal	94		33		235		63		117		-	
Percent		1.3		.5		3.2		.9		1.6		-
LATIN AMERICA												
San Jose	21	.5	28	.7	881	20.7	68	1.6	37	.9	-	-
Panama-Balboa	46	1.1	-	-	72	1.8	35	.9	32	.8	23	.6
Caracas	147	1.9	107	1.4	744	9.5	187	2.4	164	2.1	11	.1
Subtotal	214		135		1697		290		233		34	
Percent		1.3		.8		10.5		1.8		1.4		.2
GRAND TOTAL	915		3186		12669		1147		484		211	
PERCENT		1.0		3.6		14.3		1.3		.5		.2

(continued)

Table 4 (Continued)

Urban Terrain Zones
Area (In Hectares) and Percent

Cities	Urban Terrain Zones—Do31, OW, ON, and Zone Total						
	Do31		OW		ON		Zone Total
	ha	%	ha	%	ha	%	ha
EUROPE							
Helsinki	45	1.0	387	8.6	335	7.5	4483
Braunschweig	534	10.5	510	10.0	488	9.5	5110
Stuttgart	-	-	329	4.4	425	5.7	7426
Vienna	440	4.4	647	6.4	813	8.1	10032
Subtotal	1019		1873		2061		27051
Percent		3.8		6.9		7.6	
MEDITERRANEAN							
Athens-Piraeus	-	-	481	2.5	619	3.2	19217
Tel Aviv-Yafo	-	-	171	2.0	336	3.9	8549
Beirut	-	-	120	3.0	142	3.5	4025
Tunis	-	-	323	5.3	272	4.4	6117
Subtotal	-	-	1095		1369		37908
Percent	-	-		2.9		3.6	
ASIA							
Colombo	-	-	45	1.1	254	6.4	3994
Kuala Lumpur	-	-	71	2.1	178	5.4	3324
Subtotal	-	-	116		432		7318
Percent	-	-		1.6		5.9	
LATIN AMERICA							
San Jose	-	-	183	4.3	284	6.7	4256
Panama-Balboa	-	-	80	1.9	226	5.5	4111
Caracas	-	-	405	5.2	216	2.8	7815
Subtotal	-	-	668		726		16182
Percent	-	-		4.1		4.5	
GRAND TOTAL	1019		3752		4588		88459
PERCENT		1.2		4.2		5.2	

(continued)

Table 4 (Continued)

Urban Terrain Zones
Area (In Hectares) and Percent

Cities	Urban Terrain Zones--Do (Detached Buildings, Open-Set) Do1 ha	%	Do2 ha	%	Do3 ha	%	Do4 ha	%	Do5 ha	%	Do6 ha	%
EUROPE												
Helsinki	8	.2	1301	29.0	453	10.1	349	7.8	11	.3	228	6.4
Braunschweig	5	.1	620	12.1	520	10.2	316	6.2	-	-	359	7.0
Stuttgart	-	-	975	13.1	1019	13.7	271	3.6	-	-	346	4.7
Vienna	-	-	697	6.9	1027	10.2	297	3.0	-	-	991	9.9
Subtotal	13		3593		3019		1233		11		1984	
Percent		.1		13.3		11.1		4.6		.3		7.3
MEDITERRANEAN												
Athens-Piraeus	-	-	90	.5	86	.4	207	1.1	200	1.1	451	2.3
Tel Aviv-Yafo	9	.1	1031	12.1	526	6.2	949	11.1	-	-	473	5.5
Beirut	-	-	342	8.0	-	-	111	2.8	-	-	271	6.7
Tunis	-	-	177	2.9	615	10.1	146	2.4	-	-	732	12.0
Subtotal	9		1622		1227		1413		200		1927	
Percent	-	.1		4.3		3.2		3.7		.5		5
ASIA												
Colombo	-	-	119	3.0	582	14.6	124	3.1	-	-	212	5.3
Kuala Lumpur	-	-	263	7.9	1386	41.7	51	1.5	33	1.0	269	8.1
Subtotal	-	-	382		1968		175		33		481	
Percent	-	-		5.2		26.9		2.4		.5		6.6
LATIN AMERICA												
San Jose	2	.1	11	.3	393	9.2	221	5.2	-	-	268	6.3
Panama-Balboa	15	.4	180	4.4	566	13.8	341	8.3	99	2.4	278	6.8
Caracas	-	-	874	11.2	-	-	262	3.4	40	.5	226	2.0
Subtotal	17		1065		959		824		139		772	
Percent	-	.1		6.6		5.9		5.1		.9		4.8
GRAND TOTAL	39		6662		7173		3645		383		5164	
PERCENT		.1		7.5		8.1		4.1		.4		5.8

(continued)

Table 4 (Continued)

Urban Terrain Zones
Area (In Hectares) and Percent

Cities	Urban Terrain Zones--Dc (Detached Buildings, Close-Set)													
	Dc1		Dc2		Dc3		Dc4		Dc5		Dc7		Dc8	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
EUROPE														
Helsinki	-	-	76	1.7	-	-	608	13.6	-	-	-	-	-	-
Braunschweig	8	.2	916	17.9	-	-	526	10.3	-	-	155	3.0	-	-
Stuttgart	-	-	417	5.6	1742	23.5	1105	14.9	-	-	140	1.9	-	-
Vienna	-	-	551	5.5	233	2.3	993	9.9	-	-	7	.1	-	-
Subtotal	8		1960		1975		3232		-		302		-	
Percent		.1		7.2		7.3		11.9		-		1.1		-
MEDITERRANEAN														
Athens-Piraeus	-	-	2661	13.8	4465	23.2	2188	11.4	-	-	-	-	-	-
Tel Aviv-Yafo	-	-	3991	46.7	347	4.1	224	2.6	74	.9	28	.3	-	-
Beirut	50	1.2	836	20.8	226	5.6	343	8.5	-	-	-	-	65	1.6
Tunis	-	-	238	3.9	1828	29.9	354	5.8	50	.8	-	-	379	6.9
Subtotal	50		7726		6866		3109		124		28		444	
Percent		.1		20.4		18.1		8.2		.3		.1		1.2
ASIA														
Colombo	30	.8	157	3.9	1632	40.9	461	11.5	-	-	-	-	5	.1
Kuala Lumpur	38	1.1	403	12.1	234	7.0	195	5.9	34	1.0	-	-	-	-
Subtotal	68		560		1866		656		34		-		5	
Percent		.9		7.7		25.5		9.0		.5		-		.1
LATIN AMERICA														
San Jose	3	.1	332	7.8	1246	29.3	278	6.5	-	-	-	-	-	-
Panama-Balboa	18	.4	21	.5	1732	42.1	150	3.6	72	1.8	-	-	125	3.0
Caracas	-	-	-	-	2483	31.8	210	2.7	43	.6	-	-	1696	21.7
Subtotal	21		353		5461		638		115		-		1821	
Percent		.1		2.2		33.7		3.9		.7		-		11.4
GRAND TOTAL	147		10599		16168		7635		273		330		2270	
PERCENT		.2		12.0		18.4		8.6		.3		.4		2.6

This relatively low figure of 20.8 percent for the attached building urban terrain classes is a product of the extensive peripheral expansion growth that nearly all cities have experienced since about 1950. The outer edge of these attached building terrain zones is essentially the boundary of the older part of the city, that part that grew incrementally lot by lot, rather than according to larger, planned units.

Some variations are seen regionally and from city to city. Mediterranean cities, for instance (at 19.1 percent versus the overall average of 14.3 percent for the A3 class) have high proportions of attached building areas. This stems in part from the cultural practice of constructing buildings to occupy their lots fully and in part simply from having been built-up for a long time (and with relatively little loss of building stock from war damage). A very good example is Athens. A contradiction, though, is seen in Tel Aviv-Yafo, a city whose main build of area dates only from 1948 and Israeli independence.

European cities, especially German cities, had higher proportions of attached zones in pre-WW II days than they do today (discussion in Vance, 1977; Hall, 1981). Vienna--suffering relatively little war damage--also has a large remaining stock of such buildings.

Of the Latin American cities, which might be expected to follow Mediterranean characteristics, only San Jose has relatively large areas of the traditional attached forms. Both Panama and Caracas have seen extensive spread of their detached areas, along with considerable conversion of older attached areas, so that today their older, attached building zones, are overwhelmed by the newer, detached developments.

The detached, close-set building zones (Dc's) form 42.3 percent of the total that is also a result of extensive, fairly recent peripheral expansion of cities. Forming a large part of this total is the extensive areas devoted to apartments, row housing and freestanding, but closely set houses.

As with the attached classes, the Mediterranean region has percentages of the detached close-set classes equal to or greater than the average for all the cities. Tel Aviv-Yafo, again because of having experienced most of its growth in strict accordance with a master plan since 1948 and because of its great need to house extraordinarily large numbers of immigrants, has a large part (46.7 percent) of its total built-up area devoted to class Dc2 (Apartments >75% ground coverage).

The detached, open-set building zones (Do's) are composed of three basically different patterns. Some 7.5 percent (of all classes) is taken up by planned unit apartment developments. Helsinki ranks very high among cities in this class in part because of governmental assistance to housing and in part because of the suitability of such planned complexes in an area of severe winters. Athens-Piraeus, on the other hand, has an extraordinarily low representation of this class, due in part to limited space.

A similar figure, 8.1 percent is devoted to detached, open-set single family housing (class Do3). This is a figure considerably less than would be encountered in U.S. cities, especially the more recently expanding ones, but expresses the factors cited earlier (economics, cultural preference, planning legislation).

A third, and most common occurrence, is the area (5.8 percent) of the universally observed class of administrative/cultural (class Do6). These areas are such universal features as schools' campuses, governmental building complexes, and hospitals). Notably, each region deviates but little from the average for all.

The distribution of open space (nonbuilt-upon space) is also remarkably uniform in all regions with each region varying but little from the average. The spatial distribution pattern is also remarkably even.

Proportions of each of the classes within each of the three major groups (attached, detached close-set, detached open-set) vary widely (Figures 23, 24, and 25). In the attached class (Figure 23), the residential class A3 is, expectedly, far and away the largest. Residential classes--Dc2 and Dc3--are also the major representatives in the detached buildings (close-set) class (Figure 24). The relatively large area in the industrial/storage Dc4 class could be important in MOUT considerations. As would be expected, the residential classes are also large among the detached building (open-set) classes (Figure 25). The large area in the administrative/cultural Do6 class also has significant MOUT portent.

Aggregated Urban Terrain Zones

Summarizing the data in accordance with broad functional types (see Figure 26 and Table 5) provides another view of the situation. Each broad grouping of classes is examined under headings both of percent of total area and frequency of occurrence of the terrain zones within each city. For the former, the area of the classes is summed under the functional classes listed. The number of occurrences refers to the number of individual units summed from all the maps for each class.

The dominance of the residential classes is clear in the broadest aggregate view (Figure 26). Conversely, commercial areas that are so important in terms of their locations and tall buildings occupy only a small proportion of total urban area.

Looking now at the percent of total area column in Table 5, we see that 63.8 percent of space within cities is occupied by the classes that are almost entirely residential (classes A2, A3, Dc2, Dc3, Do2, and Do3). Of these, Dc3 (houses, >75% ground coverage) is the dominant, forming 18.3 percent of the space of all cities, in the aggregate. Classes A3 (apartments/row houses) and Dc2 (apartments, >75% ground coverage) are also relatively large in area. The open-set housing (Do2 and Do3) areas, while smaller within the residential group, are still large when compared to the nonresidential zones.

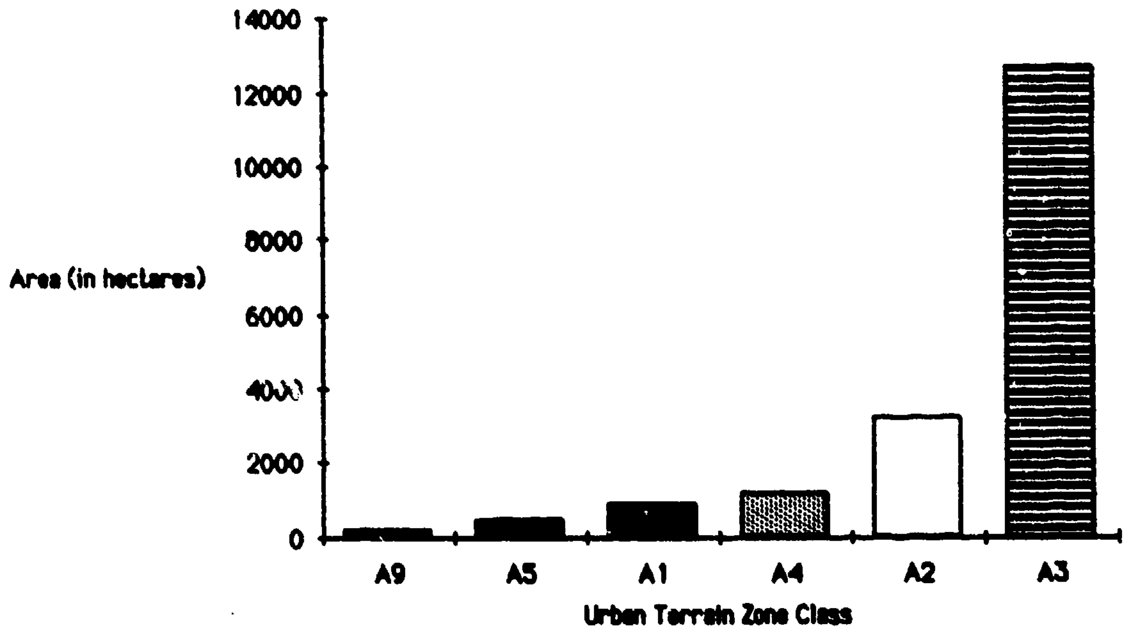


Figure 23. Urban terrain zones, attached buildings: Area.

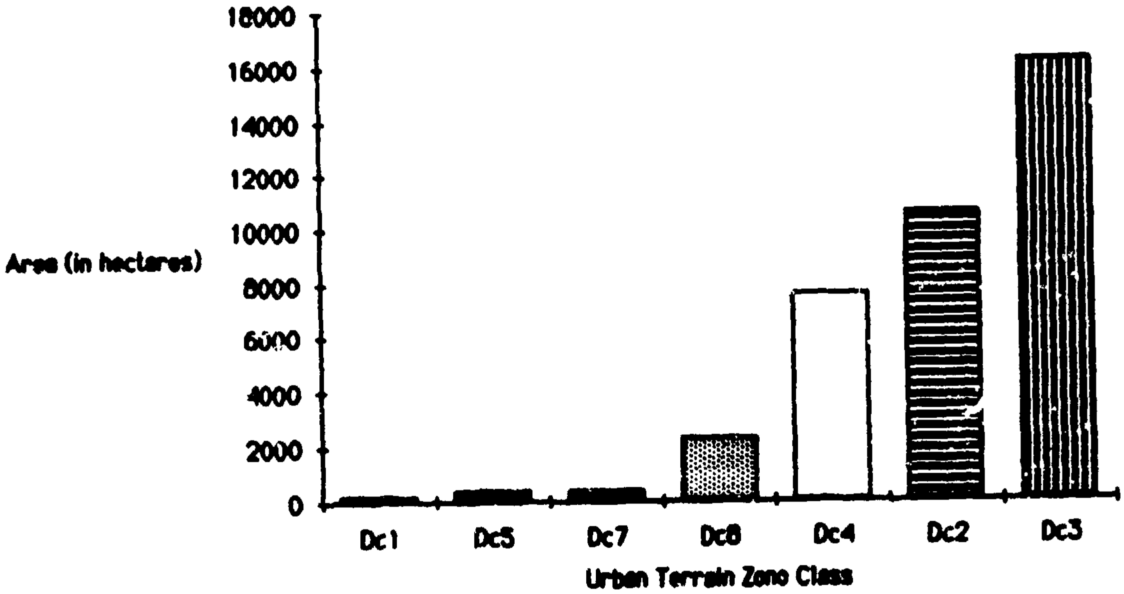


Figure 24. Urban terrain zones, detached buildings (close-set): Area.

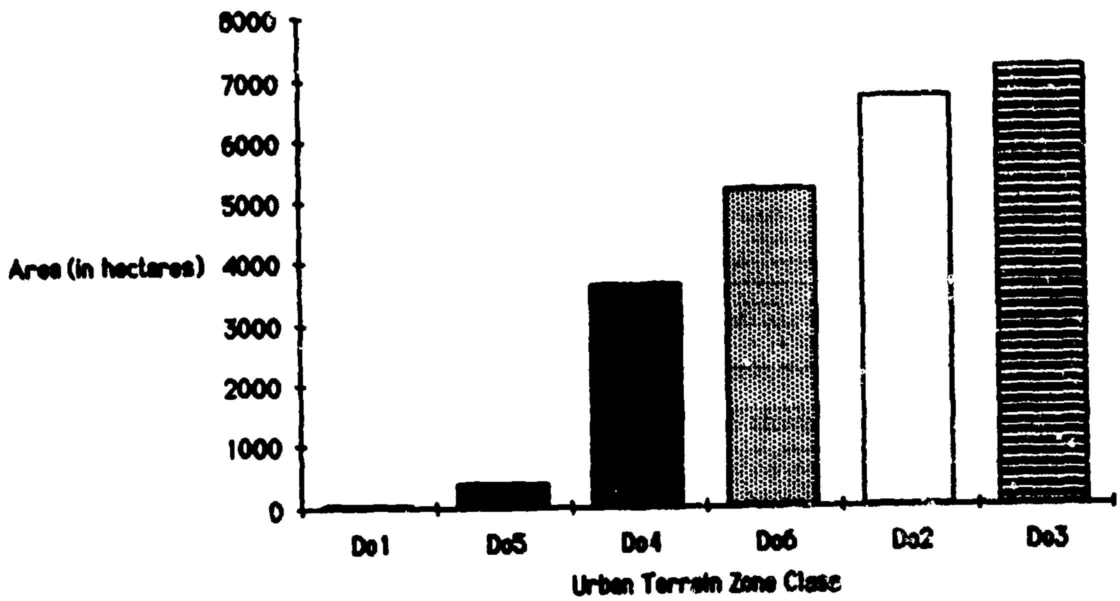


Figure 25. Urban terrain zones, detached buildings (open-set): Area.

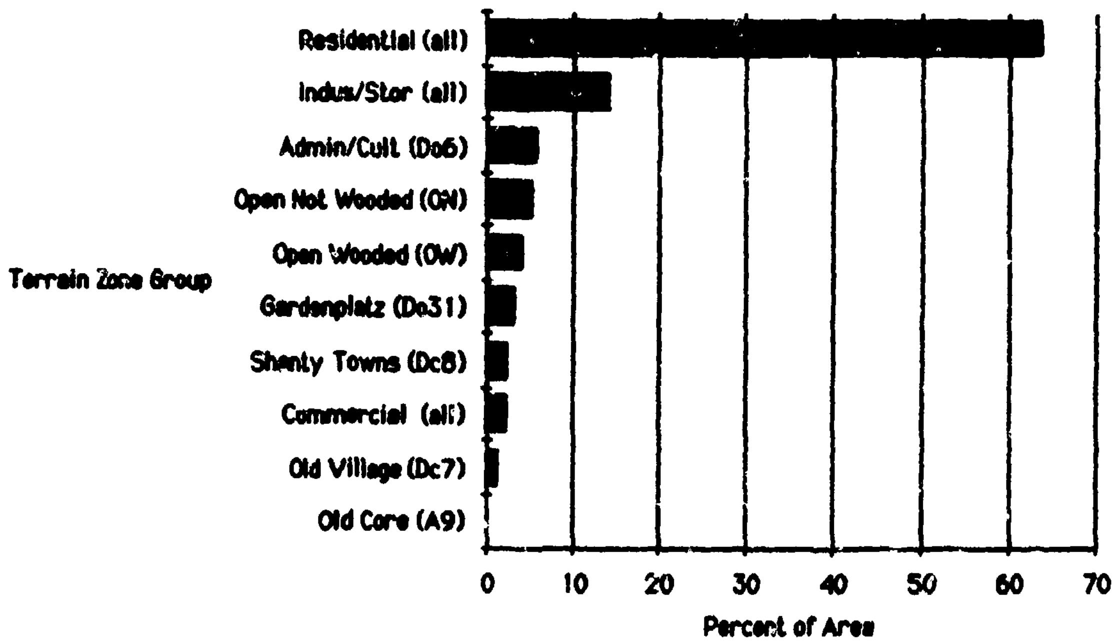


Figure 26. Urban terrain zones: Area.

Table 5

Urban Terrain Zones Grouped By Function--All Cities Aggregated

Groups	Number of Occurrences	Percent of Occurrences	Area (ha)	Ave Six (ha)	Percent of Total Area
Residential					
A2	23		3186	139	3.6
A3	74		12669	171	14.3
Dc2	146		10599	73	12.0
Do2	317		6662	21	7.5
Do3	193		7173	37	8.1
Subtotal	906	30.6	56457	62	63.8
Industrial/Storage					
A4	44		1147	26	1.3
Dc4	207		7635	37	8.6
Do4	225		3645	16	4.1
Subtotal	476	16.1	12427	26	14.1
Commercial					
A1	16		915	57	1.0
A5	17		484	28	.5
Dc1	13		147	11	.2
Dc5	18		273	15	.3
Do1	7		39	6	.1
Do5	11		383	35	.4
Subtotal	82	2.8	2241	27	2.5
Administrative/Cultural					
Do6	595	20.1	5164	9	5.8
Old Core					
A9	4	.1	211	52	.2
Old villages					
Dc7	26	.9	330	13	.4
Shanty towns					
Dc8	29	1.0	2270	78	2.6
Gartenplatz					
Do31	67	2.3	1019	15	1.2
Open, not wooded					
ON	506	17.1	4588	9	5.2
Open, wooded					
OW	272	9.2	3752	14	4.2
TOTALS	2963	100.0	88459	29.9	100.0

In terms of incidence of occurrences, the residential classes are relatively not as dominant, counting for only some 30.6 percent of all cases. This figure simply reflects the fact that homogeneous residential terrain zones in peripheral areas are extensive in area and are homogeneous in character.

Returning to the percent of total area occupied by classes, the next most extensive group of classes is that of industrial/storage, accounting for 14.1 percent of all city space. As might be expected, the railroad and dock-related class (Dc4) accounts for the dominant part of this group while the old, industrial/storage area near the core areas accounts for only 1.3 percent of the total. Truck-related, while being an extensive user of space where found, is still so new in most cities of the world that it accounts for only 4.1 percent of total space.

Administrative/cultural, as a single, distinctive class, accounts for a total of 5.8 percent of all built-up city space. At the same time, it has almost the smallest average size of individual occurrence with only 9 hectares. Many of these are schools with accompanying grounds.

Shanty towns account for 2.6 percent of all city space, but this relatively high figure is boosted by the large area (some 1696 hectares) in Caracas alone.

Commercial zones occupy a smaller amount (2.5 percent of all built-upon city space) of area than might be expected considering both their economic significance and the tall buildings with which most of the zones in this class are associated. This low figure demonstrates that the perception of such a feature as a downtown area probably comes largely from a perception of its recognized economic value plus the multiplication of surface space that occurs in multistory buildings. If we were to allow an average building height of 10 stories in the core areas (A1), the figure of 1.0 would attain far greater significance.

The remaining three classes on the summary table (German garden places at 1.2 percent, old core at 0.2 percent, and old villages at .4 percent) are very limited in total and have greater local importance than they do collectively.

Figures 27, 28, and 29 provide a graphic presentation of the rank order of urban terrain classes within functional groupings. In Figure 27, an ordered progression is seen from the A2 through Dc3 classes. A2, being in the core area, is small. A3, the bulk of residential area within the attached building groups, is large. Of the industrial/storage classes (Figure 28), the railroad/dock-related Dc4 class is twice as large as the Do4 class; the A4 class is small, as would be expected. The total area of the commercial zones (Figure 29) is small but of these, the core area A1 class is the largest while the shopping center class Do1 is the smallest.

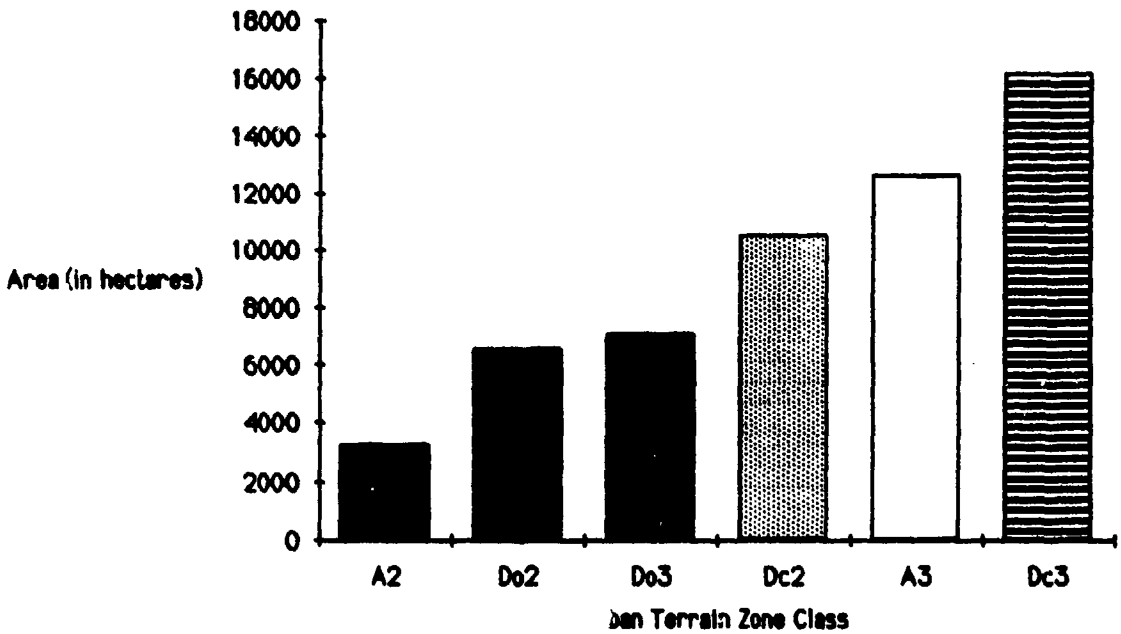


Figure 27. Residential urban terrain classes: Area.

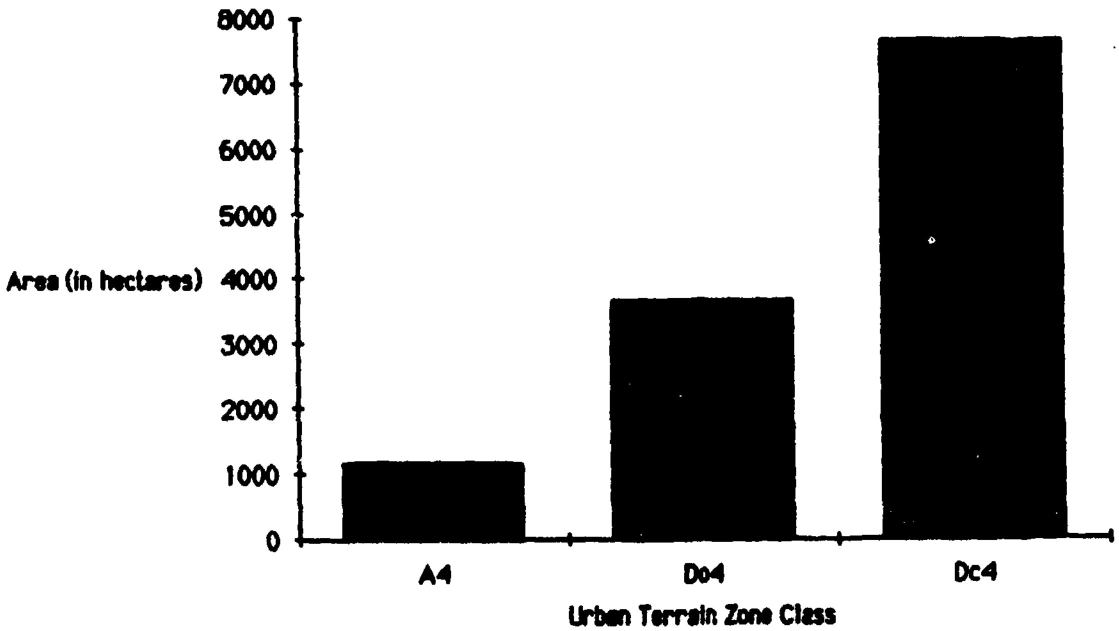


Figure 28. Industrial/storage urban terrain classes: Area.

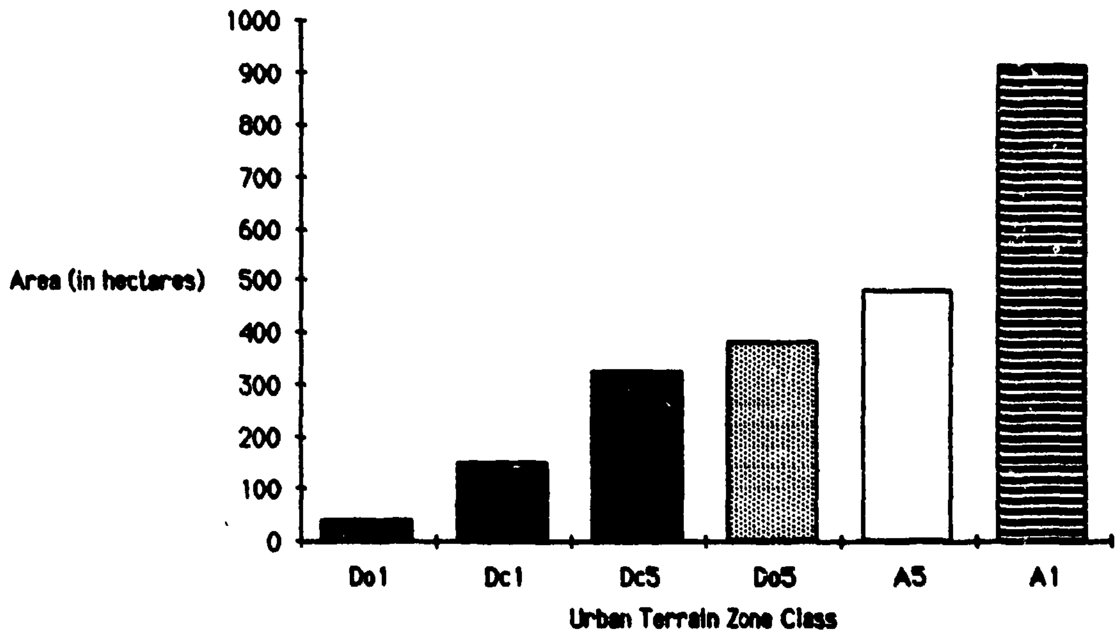


Figure 29. Commercial urban terrain zones: Area.

Figure 30 shows the relative ranked position of the area of all the urban terrain zone classes. The residential classes dominate (the highest three are Dc3, A3, and Dc2 with Do3 and Do2 close behind).

URBAN TERRAIN ZONE SPATIAL PATTERNS

The observation that urban terrain zones are replicated in cities everywhere despite regional differences in culture, level of economy, political structure and so on is demonstrated again upon examining the similar spatial patterns that emerge when maps of the spatial distribution of each urban terrain zone class (Figures 31, 32, 33, 34, and 35) are placed side by side.

In each instance, the zonal class shown on the thematic maps has approximately the same spatial distribution pattern for each city. The pattern has a definite structure: occurrences of the class share such features as being a similar distance away from the center of the city (or in the center in the case of terrain zone A1), the relation to railroads, being about the same size, and with quite a uniform spatial distribution. Each of the zones examined is discussed below.

Zone A1: Core Area

The core areas (See Figures 31 through 34)--by definition in the center of the city--are small in area relative to the bulk of the metropolitan area of the city (or combined cities). In the aggregate, they form only 1.0 percent of total surface area; counting floor space would, of course, significantly increase this zone's importance. For the landlocked cities, they lie approximately at the physical center of the city (with the exception of Stuttgart where expansion of the city to the south is restricted by topographic barriers).

Vienna has the classical Altstadt (or old city), an area that has always been the core of the city and has been preserved as that today. It has the oldest buildings (a large proportion of which are mass construction in type) and narrow often treacherous streets (indeed, many of them have been permanently set aside for pedestrian use only).

In Helsinki, a port city, the old core is adjacent to the harbor. Although it is the site of a high proportion of older buildings, it has a grid street pattern, one that reflects the planning of the whole city as an adminitrative center going back to Russian times (1809-1917).

Stuttgart has a center that has been largely rebuilt in the process of clearing aerial bombardment damage in World War II. The original irregular street pattern has been somewhat modified during the process by straightening and widening arterial streets. Also, in modern times, the main street through the area, along with some connecters, has been converted to being strictly a pedestrian way.

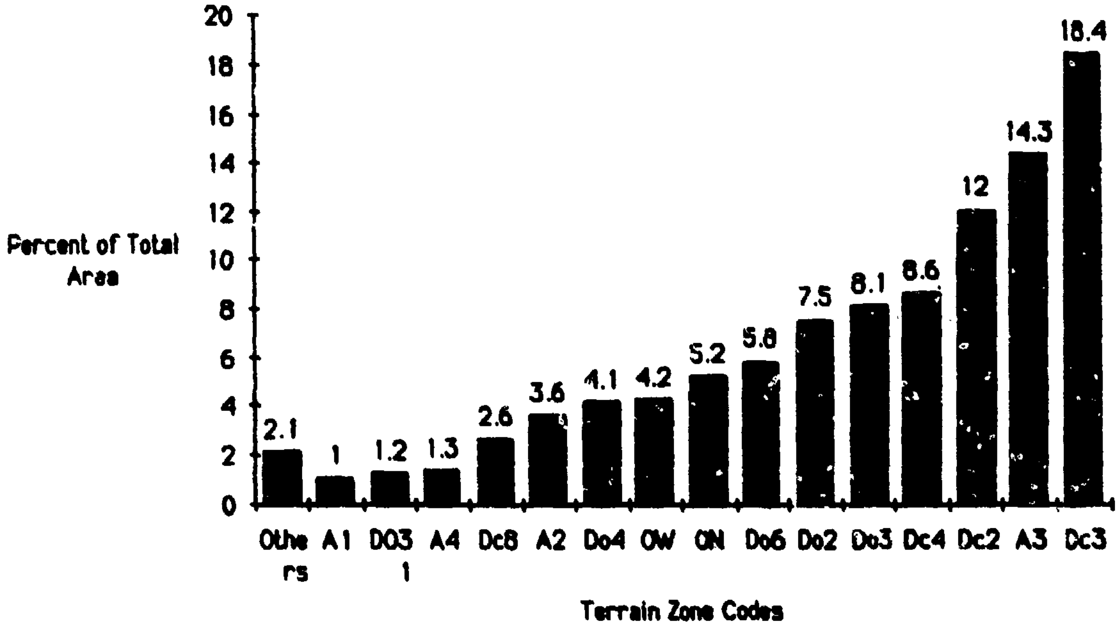


Figure 30. Terrain zone areas: Percent.

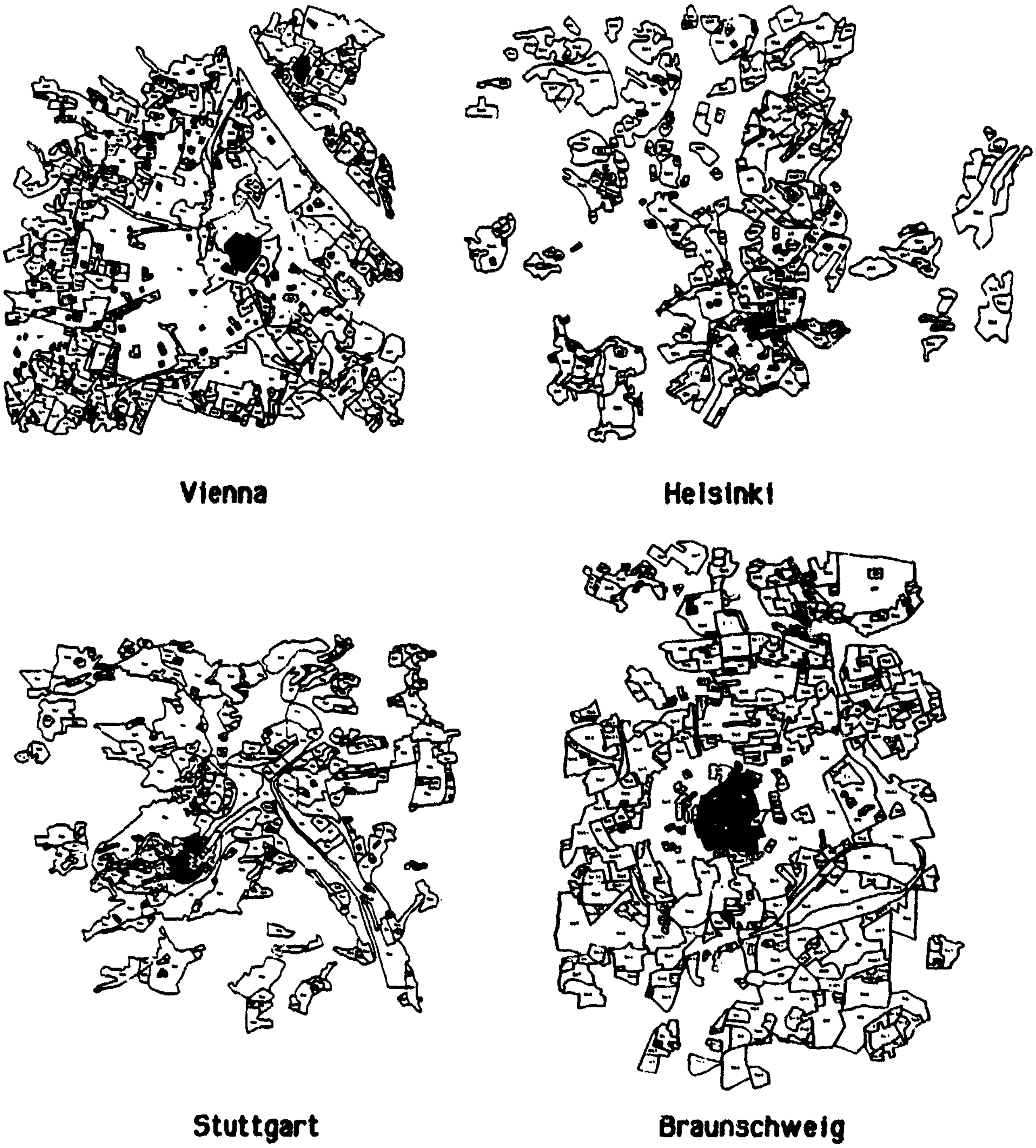


Figure 31. Urban terrain zone A1 (core area): European cities.

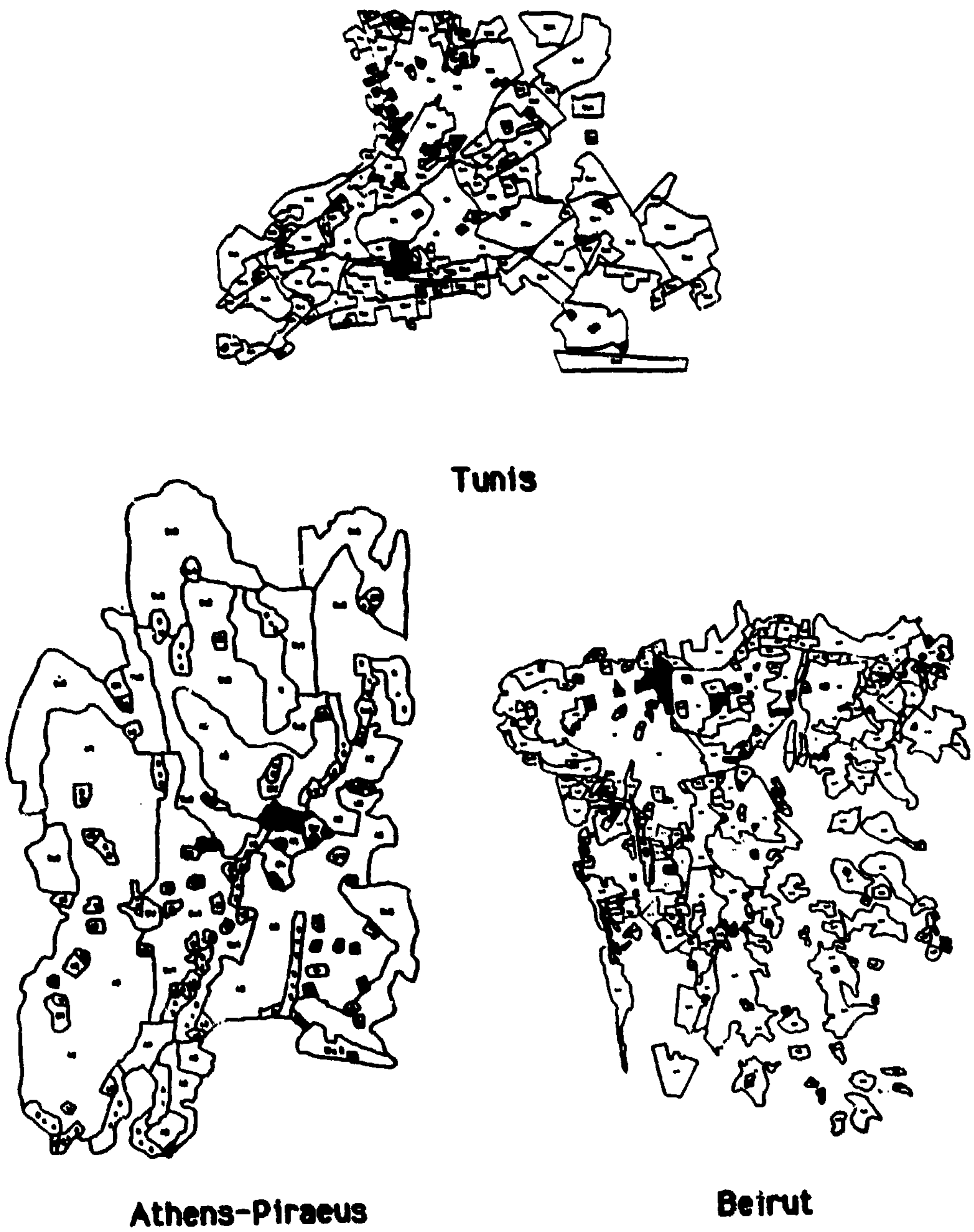


Figure 32. Urban terrain zone A1 (core area): Mediterranean cities.

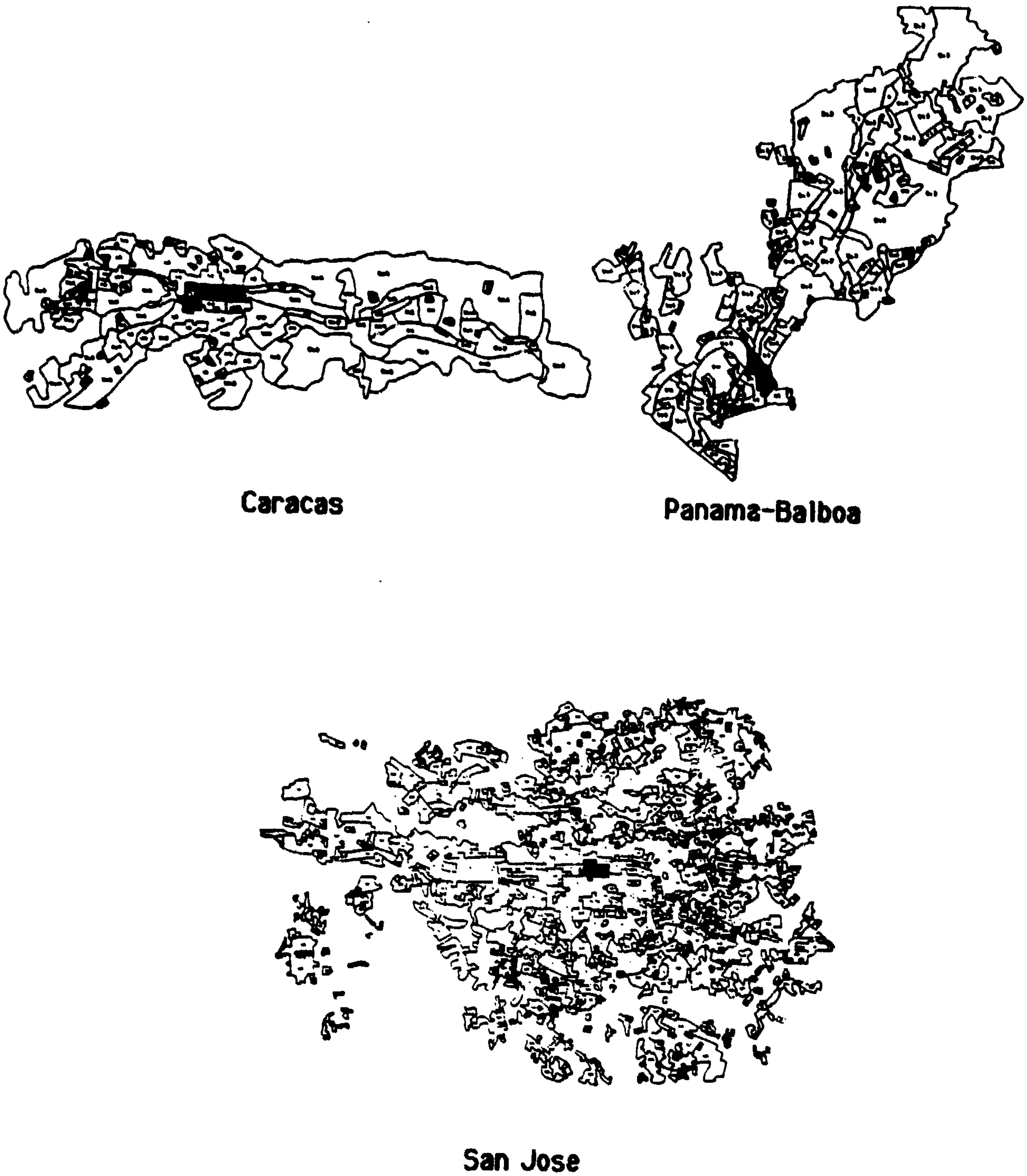
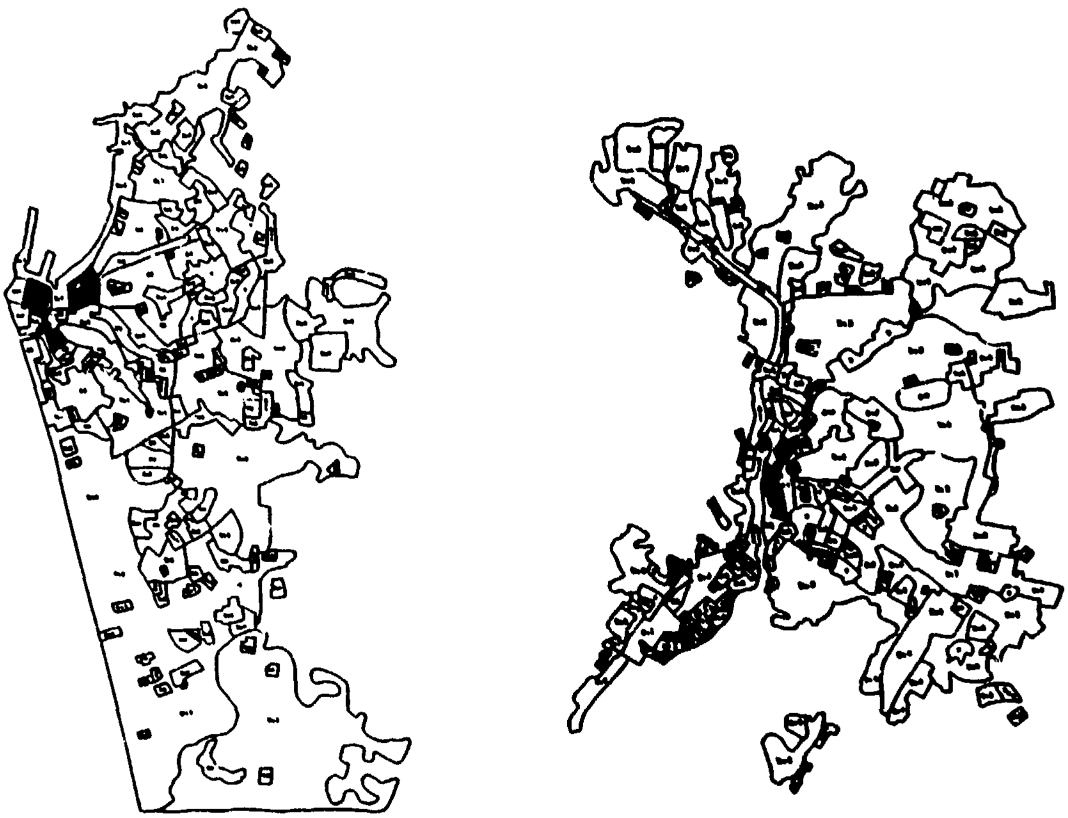


Figure 33. Urban terrain zone A1 (core area): Latin American cities.



Colombo

Kuala Lumpur

Figure 34. Urban terrain zone A1 (core area): Asian cities.

The core area of Braunchweig is the most well-defined of all the cities as it represents the area that was bounded by the city wall for a long part of its history. The level of bombing damage was high. Accordingly, most of the old mass construction buildings were destroyed or have since been razed in the process of modernizing the city. As with other badly damaged German cities, the essentially irregular street pattern has been given more order.

Three of the Mediterranean cities--Tunis, Athens-Piraeus, and Beirut--have A1 core areas. Tel Aviv-Yafo because of its rapid change, has none. The zone in Tunis lies just inland--a typical location--from the port and dock area and just adjacent to the old Medina. Beirut is large enough and complex enough to have two representatives of the zone.

The Latin American cities of Caracas, San Jose, and Panama have tightly defined cores. The A1 zone in Caracas was in the approximate center prior to the expansion of the city to the east. The core area of San Jose is the old center having been laid out in Spanish colonial times. Streets in the core area of Caracas are wide boulevards while those of San Jose are (with one exception) narrow, although straight having been laid on a grid pattern by the colonial founders. The core area of Panama City is bounded by the bay on one side and has the traditional narrow streets of colonial cities. The center of Balboa is not a core in the traditional sense but is the product of city planning as the Canal Zone was developed.

In Asia, Colombo has two core areas as is typical of former British colony port cities in South Asia. The British-founded center (Fort Colombo) demonstrates the regularity of planning while the nearby area (Pettah) is what the British referred to as the "native quarter." Kuala Lumpur has a single A1 center that remains as its principal business area. A fair amount of it, however, has been razed to make way for a new Dc1 center of high-rise office buildings.

The latter has, to this day, a high proportion of simple brick buildings and narrow and irregularly patterned streets.

Zone Dc4: Industrial/Storage, Railroad/Dock-Related (Figures 35 through 38).

Multiple function cities (as opposed to such small, single function cities as resort towns) everywhere have distinctive zones that are devoted to industry/storage, developed as a result of the presence of rail lines or docks. These zones have buildings that are linear in shape and are separated by narrow strips for rail lines or docks. Cities of any appreciable size have several discrete and separated zones coming as a result of having several railroads, docking areas or, in the case of large port cities, both. The shape of the zones themselves tends to be angular and narrow.

Of the European cities, Vienna has widely distributed rail/dock-related industrial/storage zones both in the older part of the city along rail lines, which converge on this capital city, and across the Danube to

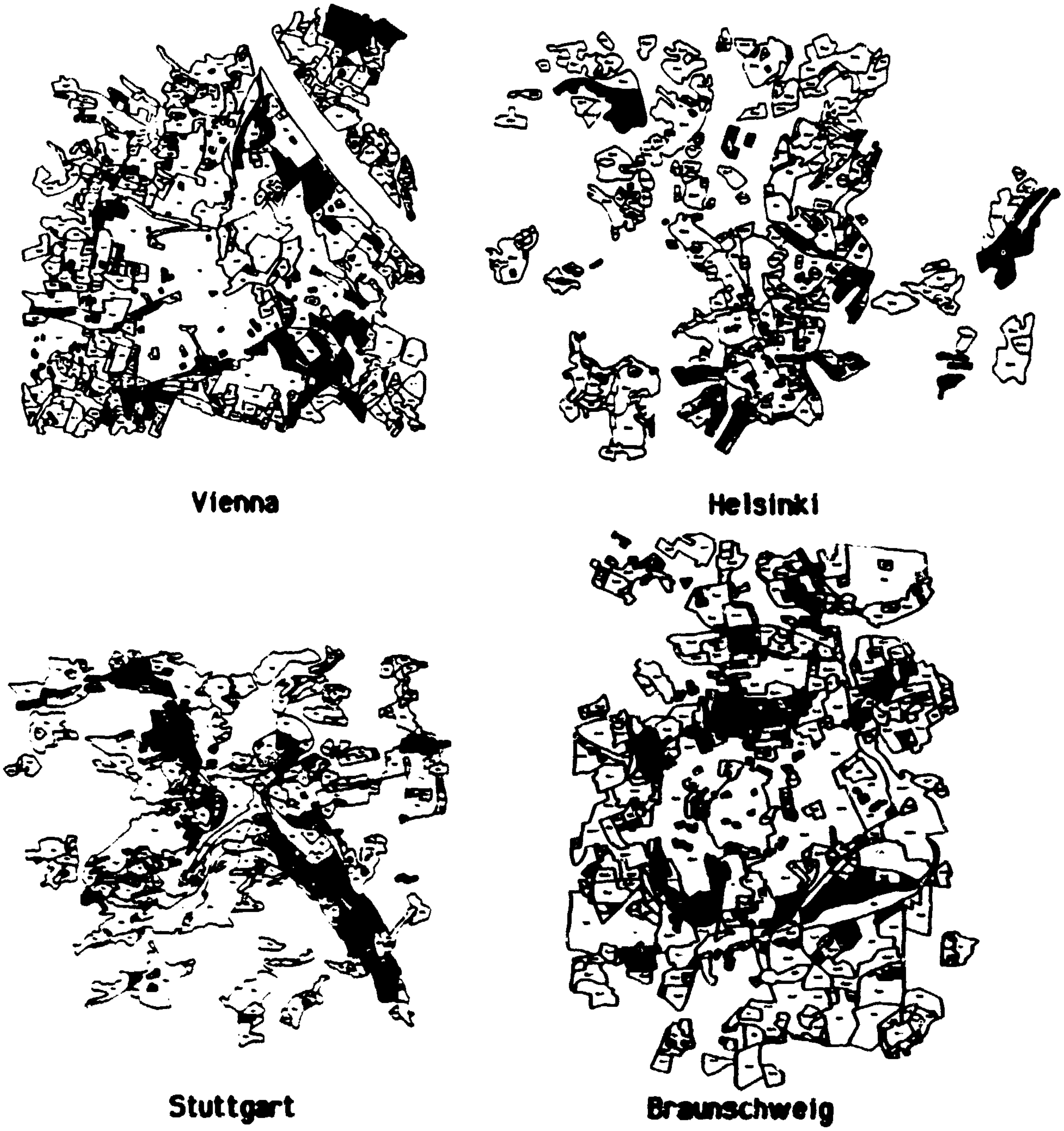


Figure 35. Urban terrain zone Dc4 (industrial/storage): European cities.

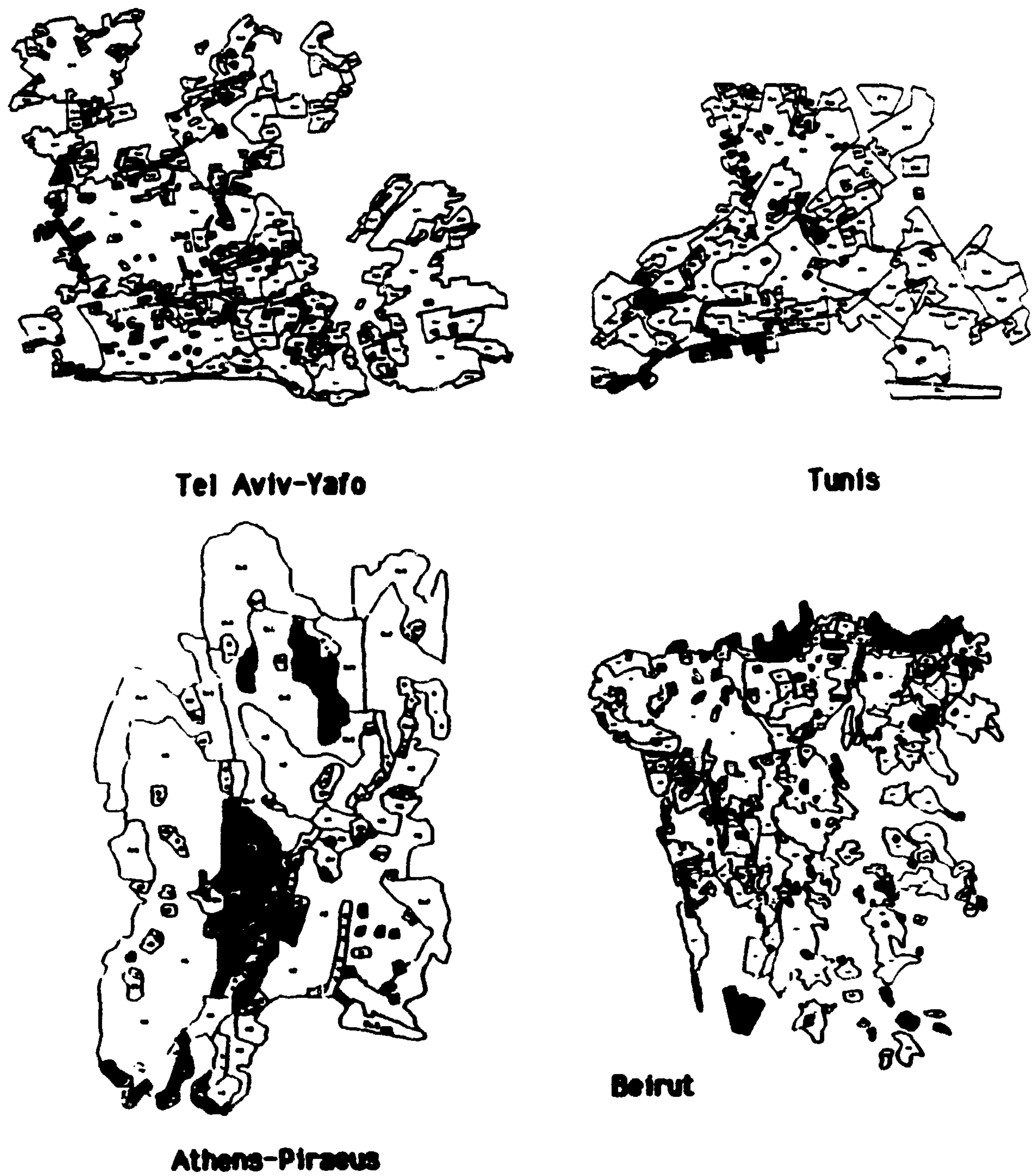


Figure 36. Urban terrain zone Dc4 (industrial/storage): Mediterranean cities.

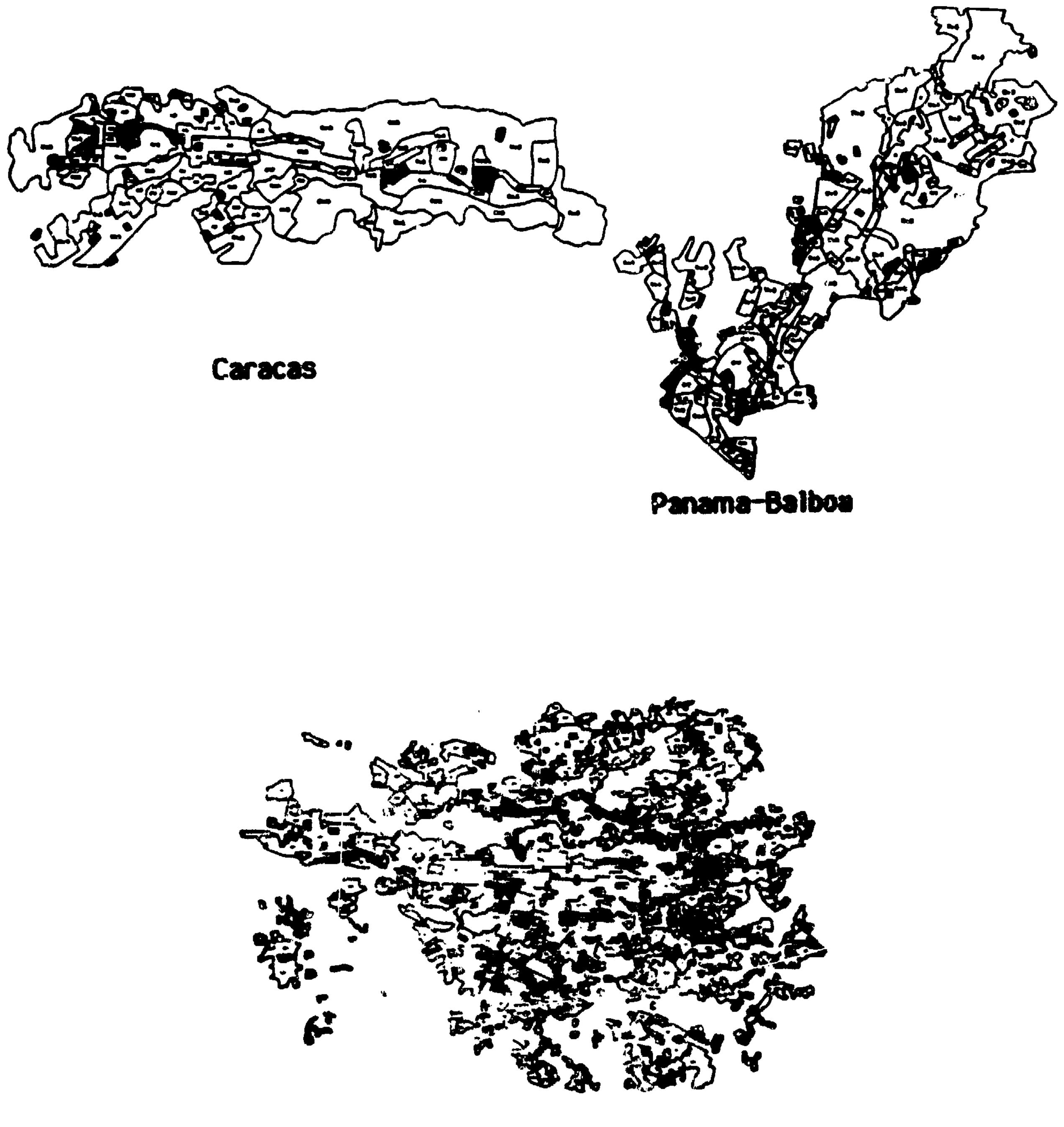


Figure 37. Urban terrain zone Dc4 (industrial/storage): Latin American cities.

Colombo

Kuala Lumpur

Figure 38. Urban terrain zone D-4 (industrial/storage): Asian cities.

the northeast. As with Helsinki, Vienna is a capital city and the largest city in the country and is accordingly the center for much of this type of activity.

Only Helsinki (in this European group of cities) is an ocean port city (not counting the significance of Danubian navigation in Vienna) and thus is the only one possessing a combination of Dc4 areas that represent both dock and rail relationships. In Helsinki, the dock areas are to the south while the interior areas are along railroad lines; together, they form the locale for much of the commerce and industry of all of Finland.

Stuttgart's industrial/storage urban terrain zones are both widely distributed and large in area. The whole zone on the southeastern side is occupied mostly by the works of the Mercedes-Benz Corporation. This area follows the criteria for the zonal delineation thanks partly to the railroad and partly to the canalized portion of the Neckar River on which raw materials for industry travel.

Braunschweig (see earlier description of this same map) clearly has its Dc4 areas lying along rail lines surrounding the core and adjacent residential area. Braunschweig indeed comes the closest of any city in the study to displaying a concentric ring pattern of terrain zones.

Several examples of industrial/storage urban terrain zones are seen in the Mediterranean cities. These lie at a similar distance from the core areas of these cities (with the exception of Tel Aviv-Yafo, which has no modern core).

Tel Aviv-Yafo has Dc4 areas both at the dock area and inland along the rail lines. Tunis shows a similar pattern (with the harbor on the eastern side) and rail lines in the interior. Athens-Piraeus shows a similar pattern with the dock area of Piraeus (on the southeastern side of the city), a large industrial/storage area lying in between Piraeus and Athens, and two other areas lying to the north. Beirut also combines its dock areas to the north of the city and some railroad related areas to the interior.

In the Latin American cities group, Panama-Balboa has both dock-related representatives of the class on the western (canal side) and railroad-related ones to the northeast. Caracas has Dc4 areas at both ends of the trench-like valley it occupies. In San Jose, the rail areas lie both to the north and to the south of the core area.

Colombo, being a port city with the country's major rail lines leading from the port to all parts of Sri Lanka, has Dc4 industrial/storage areas in both locations. The docks are along the northwestern side (along the artificial harbor) and to the interior, mainly in the northern half of the city. The Dc4 area of Kuala Lumpur is limited to the area along the main railroad.

Zone Do2: Apartments, Less Than 75% Ground Coverage (Figures 39 through 42)

Because high land values near the core make the wide spacing of buildings on their lots uneconomic, the space consuming Do2 class is found mostly at the periphery of each of the study cities. These planned apartment complexes require a fair amount of ground space for the apartment buildings and associated land uses, like parking and shopping facilities.

The European study cities have a large number of Do2 zones. As expected, and conforming to theory, most are located at the periphery of the city. Many are seen in Vienna in a band at the edge of the city. A similar pattern is seen in Helsinki, Stuttgart, and Braunschweig. In all instances, these are clusters of high-rise, modern, reinforced concrete-framed apartment buildings. Most are freestanding structures, usually long and linear in shape and surrounded by open, landscaped surface with parking areas interspersed. Virtually all have long, clear lines of sight in all directions (this often means looking both inward toward the balance of the built-up area and outward to the open countryside). Having large populations and thus requiring a high degree of access, they are frequently located along major arterials.

Following a definite European pattern are the cities of the Mediterranean area. Tel Aviv-Yafo, as part of its effort to construct new housing for its many immigrants, includes a number of Do2 housing units in its general development plan. As usual, they are located at the periphery of the city reflecting the recent trend toward larger, multifamily structures. Tunis has an incipient development of its own, again with units at the edge of the city. Athens-Piraeus, although largely a city of apartments, has few representatives of this open-set class; most of its apartments are in the Dc2 class. Beirut also has a large area of close-set apartments but does have some of the more open Do2 class located especially in premium coastal areas and in areas in the mountains to the east.

The pattern in Latin American cities is (with the exception of Caracas) not as intensive as that found in Europe. Panama City has one major new area of this class (as well-developed as any in European cities) and only a few lesser ones. The phenomenon has only barely come to San Jose, a city which has so far expanded onto surrounding agricultural land that has been plentiful enough to allow the construction of low-rise structures and indivdual houses.

In Asia, Colombo has limited development along this line reflecting the country's general economic backwardness. Kuala Lumpur has several such developments in keeping with its modernism.

Zone Do3: Houses, Less Than 75% Ground Coverage (Figures 43 through 46)

Freestanding houses, not just a phenomenon of U.S. cities, are found widely distributed in the international cities studied here. As their U.S. counterparts, they are found occupying less expensive land at the periphery of the city. Tracts of them, ordinarily fairly large, are planned units built in recent years.

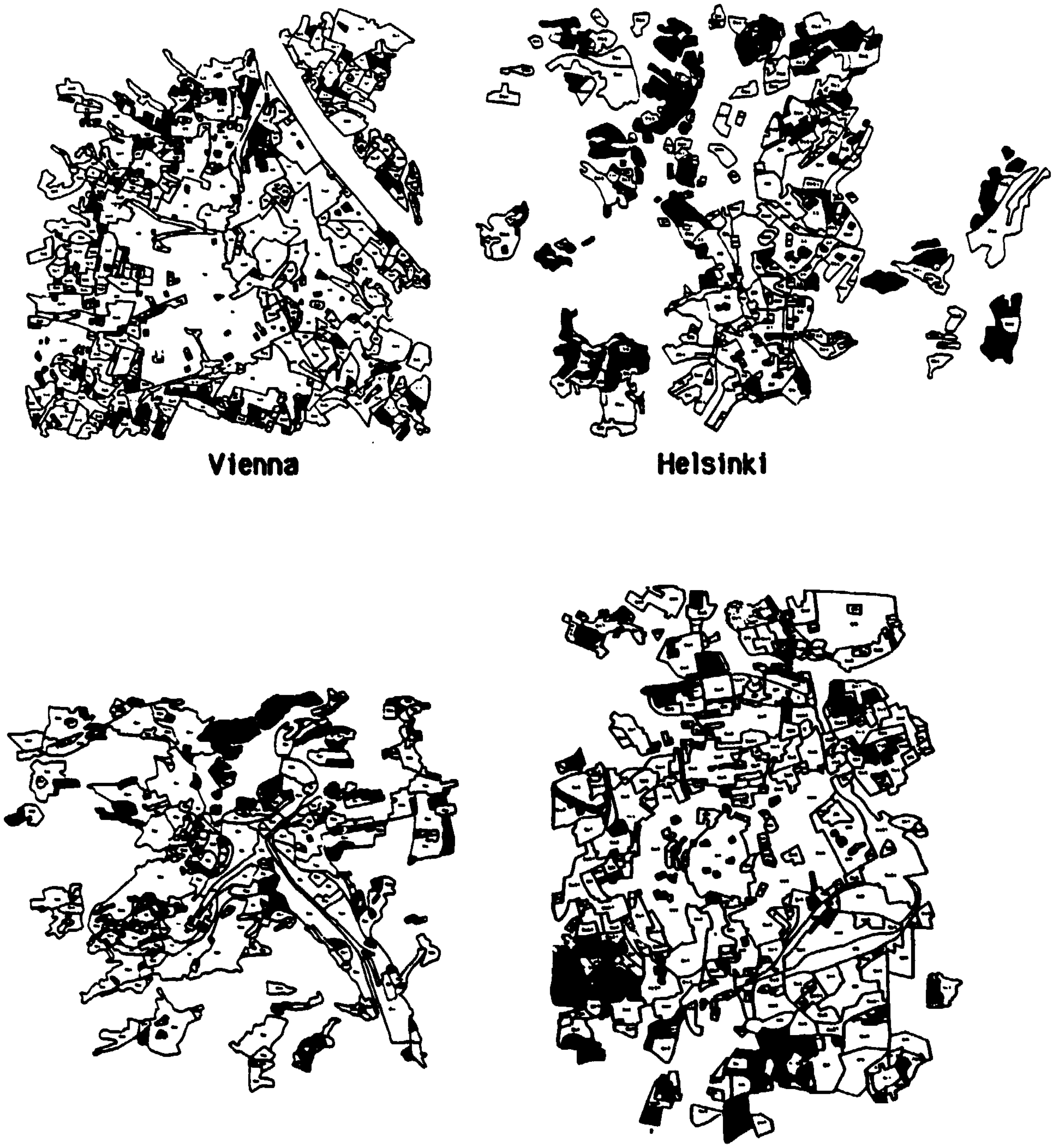


Figure 39. Urban terrain zone D^2 (apartments, open-set): European cities.

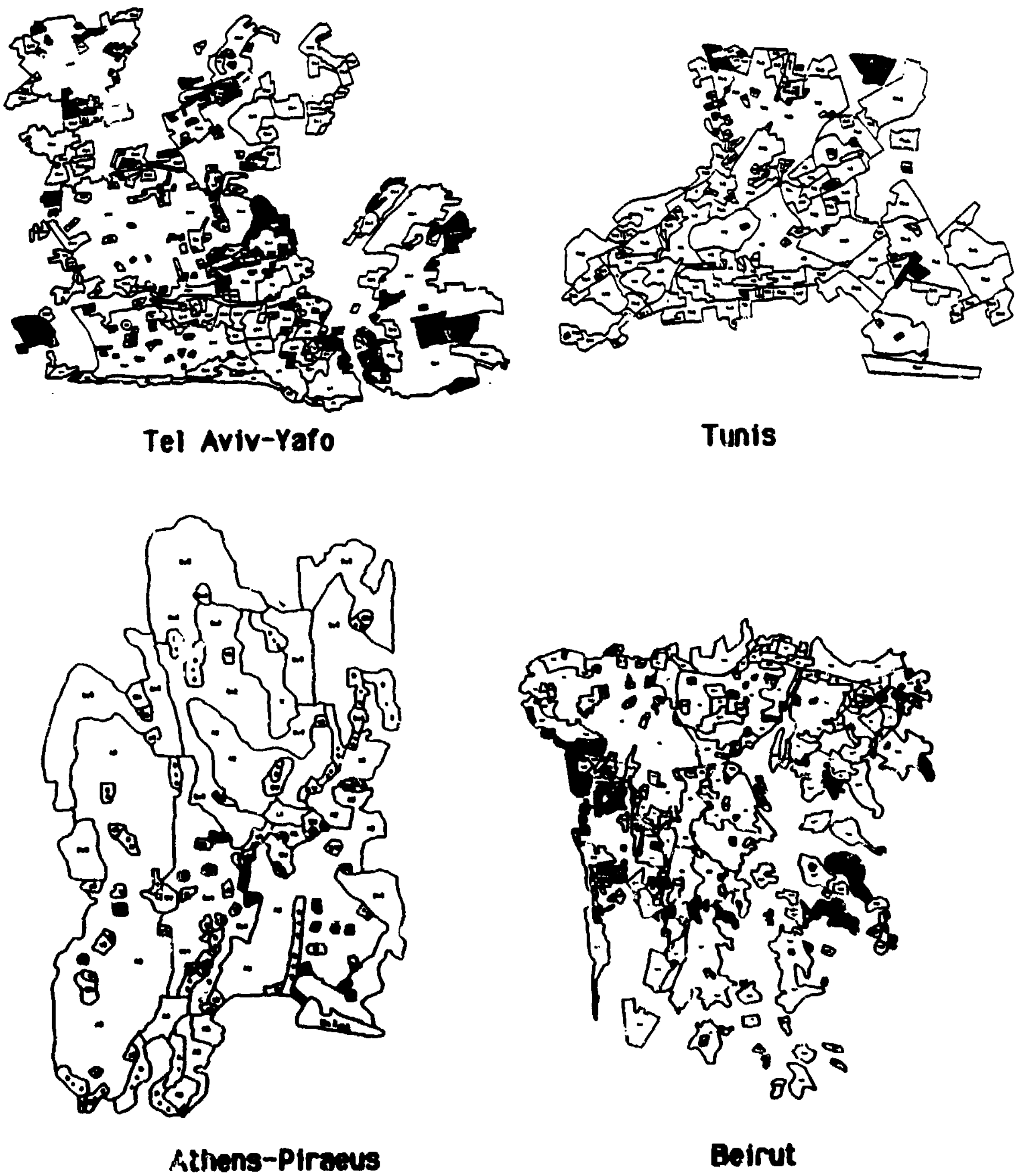


Figure 40. Urban terrain zone Do2 (apartments, open-set): Mediterranean cities.

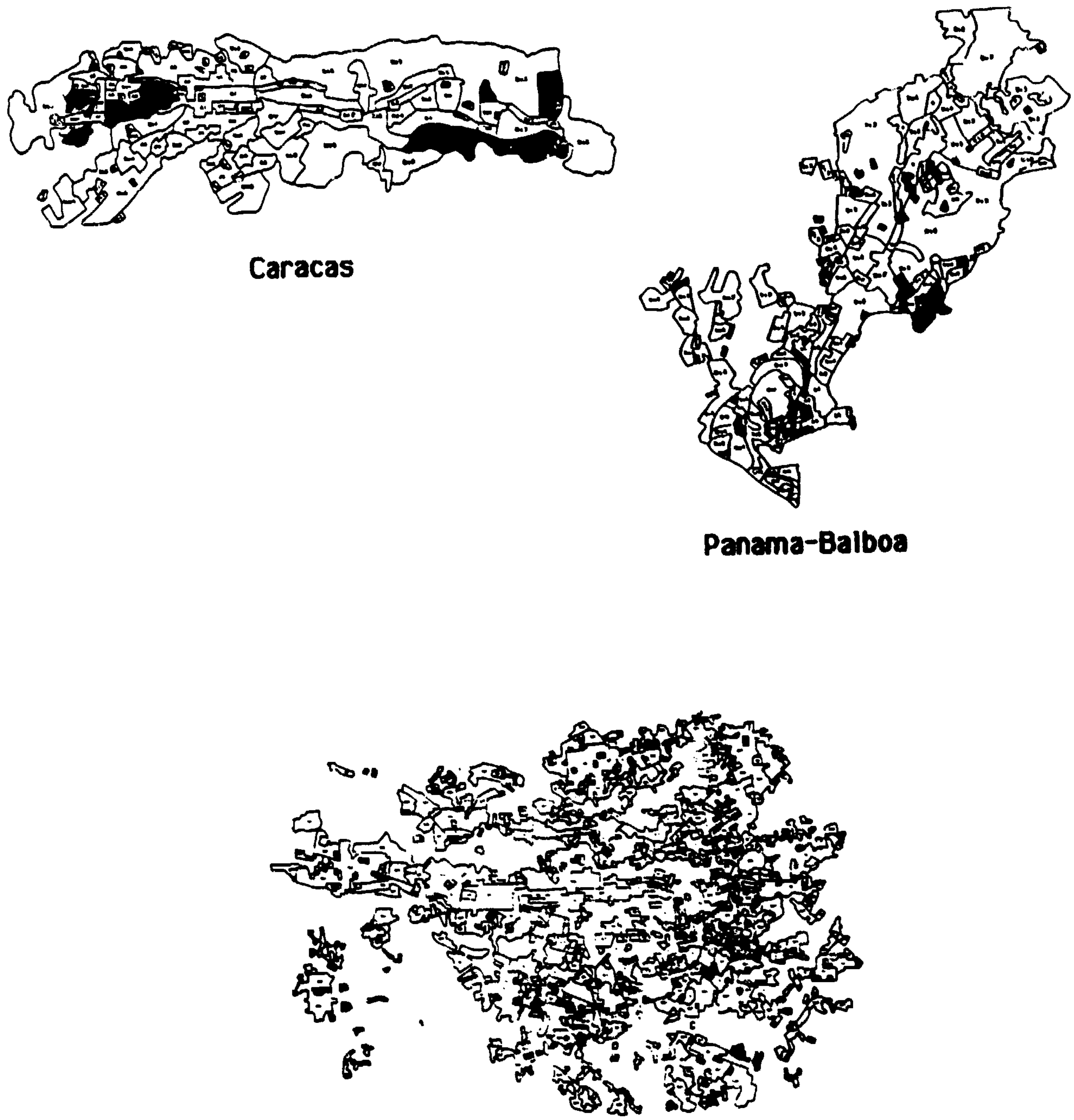


Figure 41. Urban terrain zone Do2 (apartments, open-set): Latin American cities.

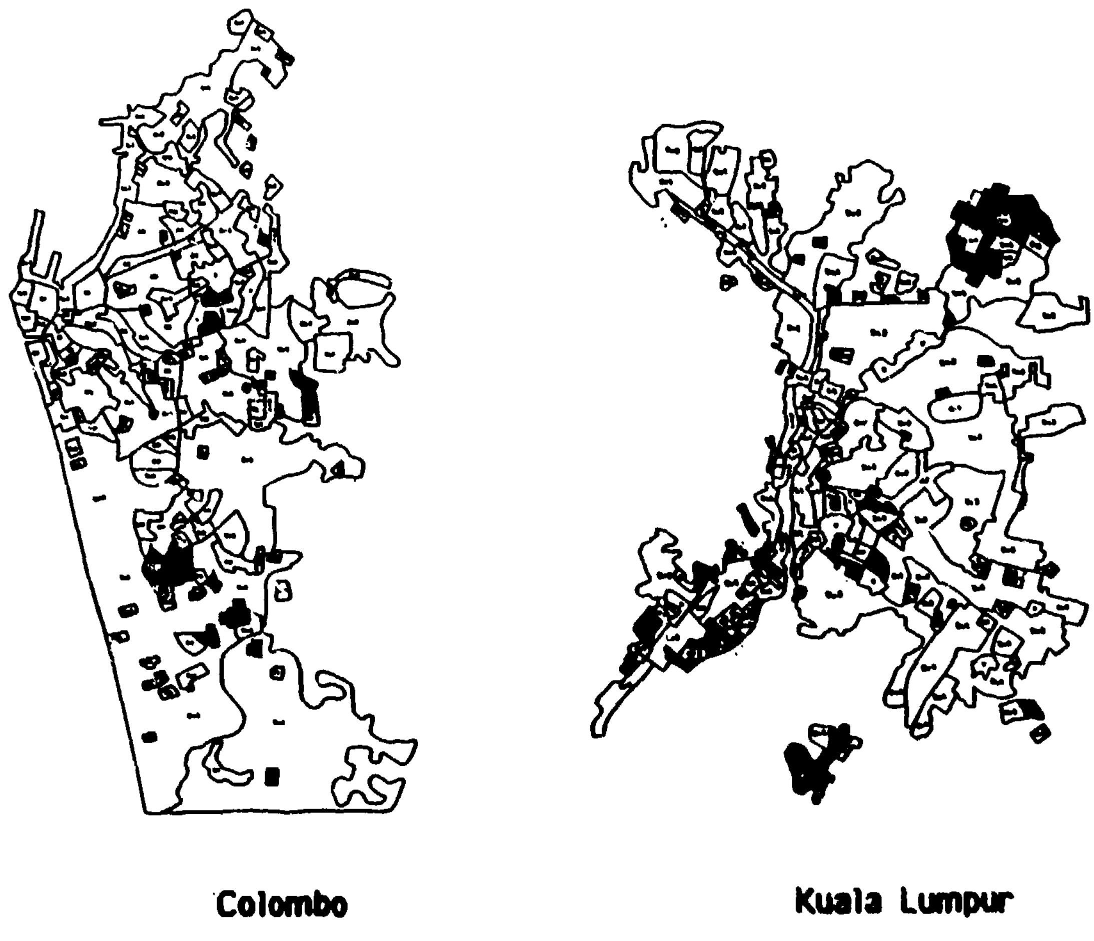


Figure 42. Urban terrain zone Do2 (apartments, open-set): Asian cities.

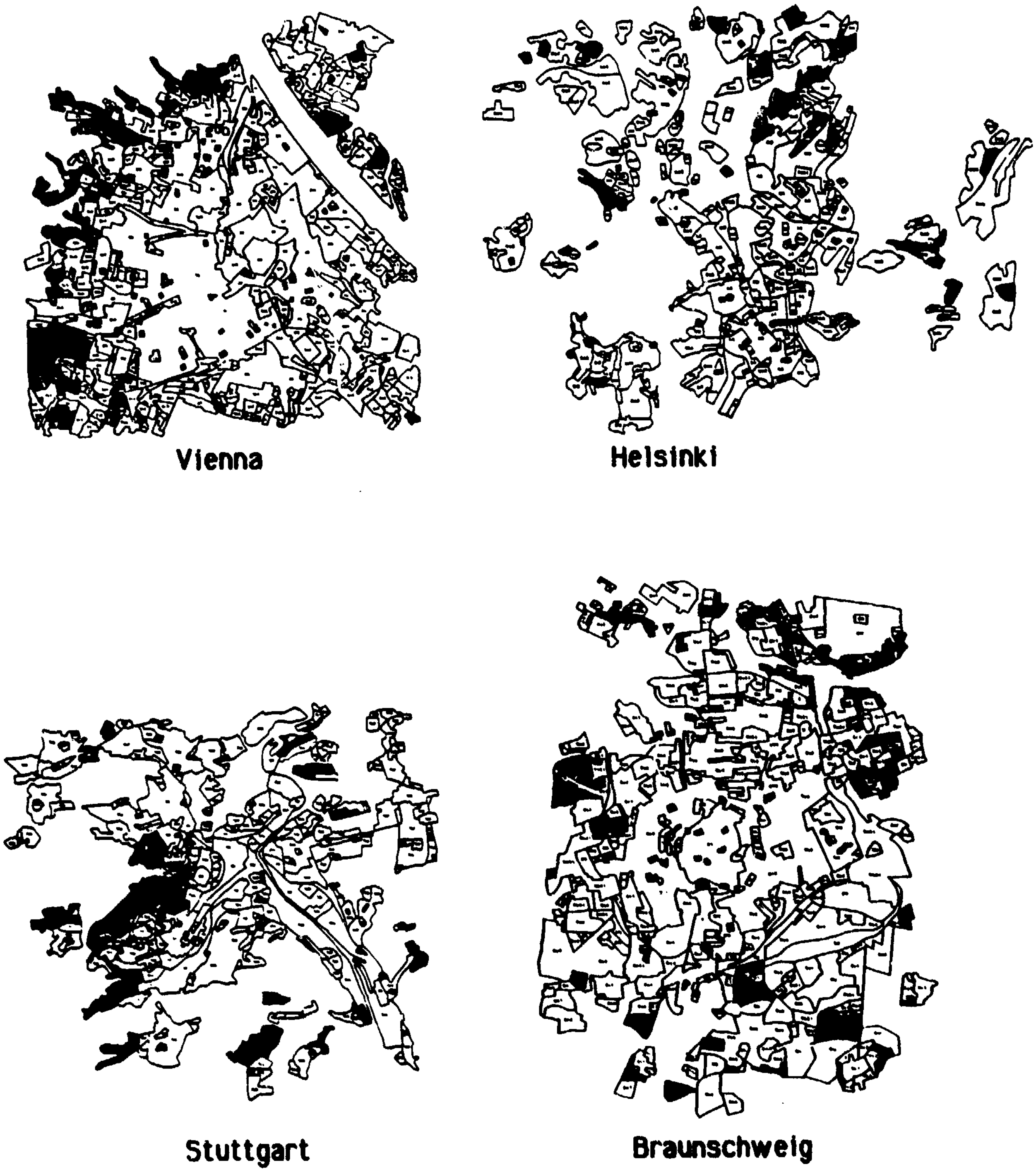


Figure 43. Urban terrain zone Do3 (houses, open-set): European cities.

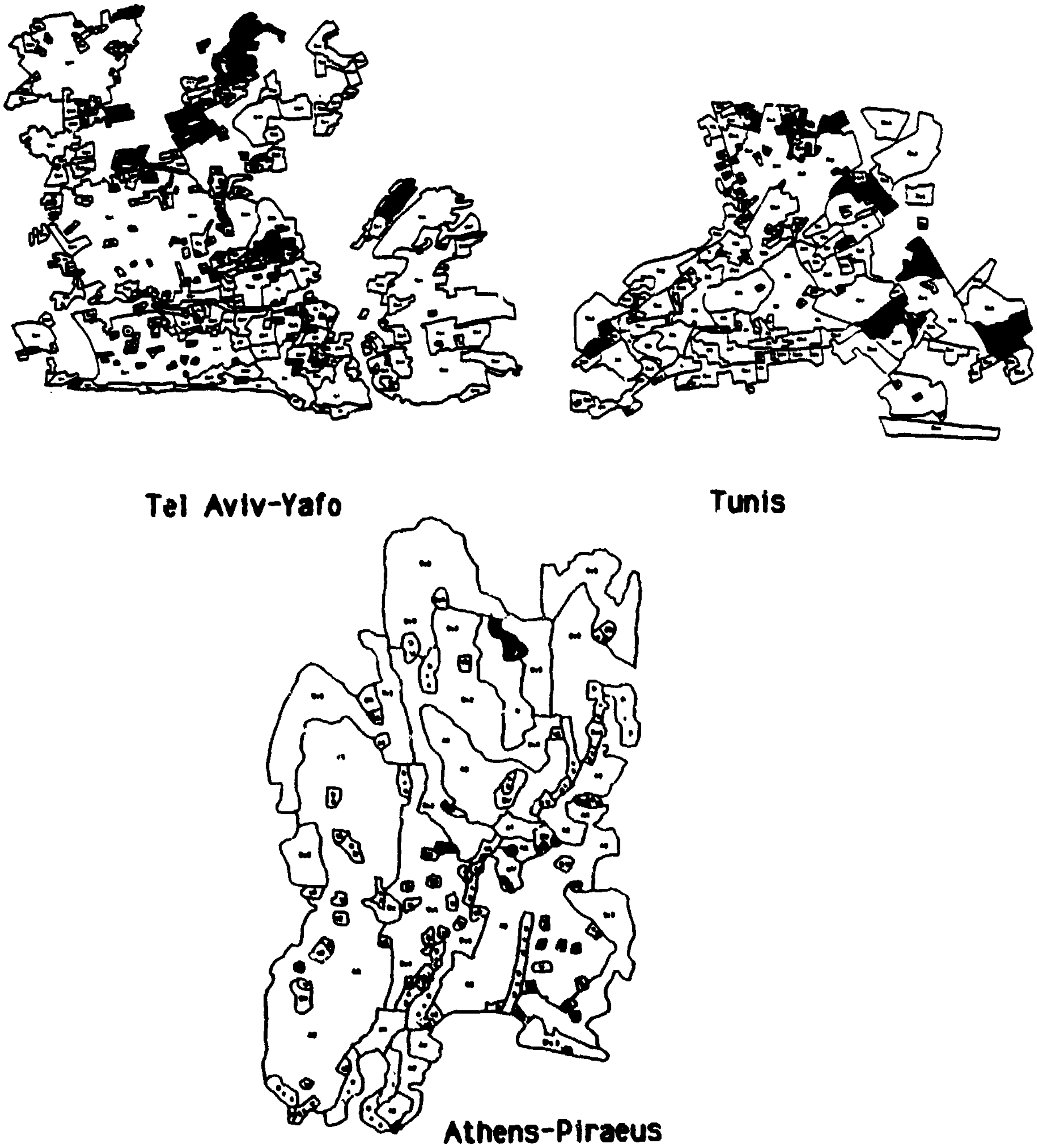


Figure 44. Urban terrain zone Do3 (houses, open-set): Mediterranean cities.

Panama-Balboa

San Jose

Figure 45. Urban terrain zone Do3 (houses, open-set): Latin American cities.

Colombo   Kuala Lumpur

Figure 46. Urban terrain zone Do3 (houses, open-set): Asian cities.

The total space devoted to this phenomenon and the pattern vary considerably from region to region. For the European cities, the occurrences at the periphery of the city, but not in the area lying toward the core area, reveal that this mode of urban form has not been part of the earlier development but has happened only in recent times. In other words, these areas at the edge of the city are quite similar to the situation with rapidly expanding U.S. cities. In all cases, these zones lie some several kilometers from the core of the city. While in all four European cities--Vienna, Helsinki, Stuttgart, and Braunschweig--the instances of this class are most often part of the outermost tier of functional zones, they do not form a solid ring around the edge of the city: other uses, such as industrial/storage and apartments are their neighbors. This fact is potentially a useful one in appraising potential MOUT operations.

Some freestanding housing exists in the Mediterranean cities but the prevailing close-set detached housing, or even attached housing (the Dc classes or the A classes) has been such a significant part of the culture of the area that little of the open-set housing has been constructed. Still, some are seen in the newer, peripheral developments of Tel Aviv-Yafo and Tunis. Little occurs in Athens-Piraeus and none in Beirut (at least in the area mapped, as determined by the extent of the topographic base map used).

The tendency for constructing higher density residential tracts in Latin American cities--following largely the example of the Mediterranean colonizing countries--means that here as well, the occurrence of detached housing is slight. The readily explained exception is in Panama-Balboa where the occurrences in the southwestern section of the joint city are part of U.S.-designed and built Balboa. The area in the northeastern part of the city is reminiscent of new developments in Tunis and Tel Aviv-Yafo. Developments in San Jose are also at the far periphery of the city.

Colombo has one large area of low-density housing occurring in the southernmost part of the city. Freestanding housing elsewhere is more dense and accordingly falls in the Dc3 class. Again, Kuala Lumpur has several such areas thus expressing its affluence.

Zone Dc6: Administrative/Cultural (Figures 47 through 50)

Of all the zonal classes, the administrative/cultural class is the most evenly distributed throughout each city. The reason lies in the nature of the function with many of the occurrences serving a local part of the city, a neighborhood school or church, for instance. Governmental areas are found in both core areas and in suburbia. College campuses and hospitals are also found widely in every city.

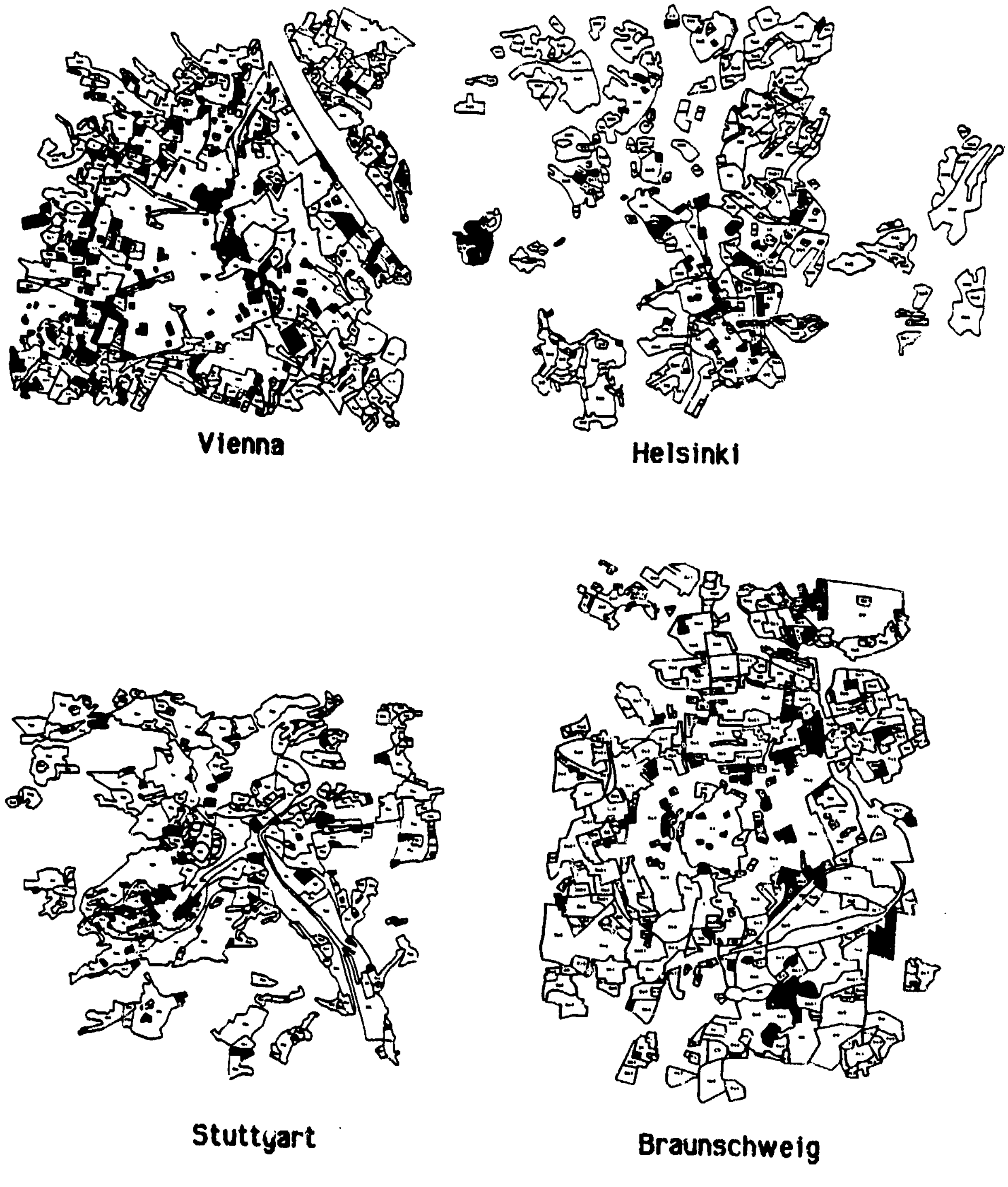
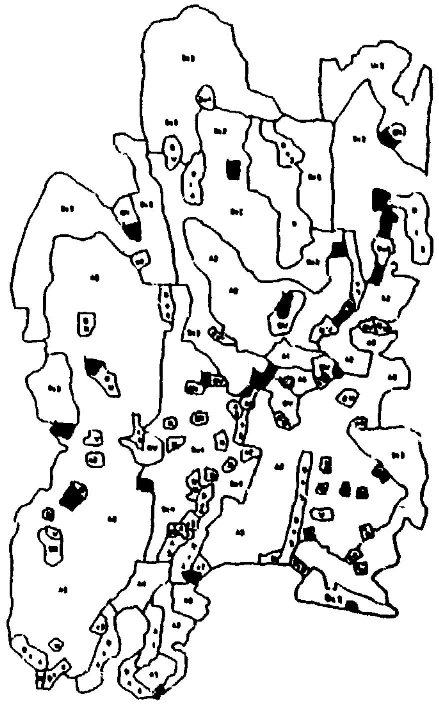


Figure 47. Urban terrain zone Do6 (administrative/cultural): European cities.

Tel Aviv-Yafo

Tunis



Athens-Piraeus

Beirut

Figure 48. Urban terrain zone Do6 (administrative/cultural): Mediterranean cities.

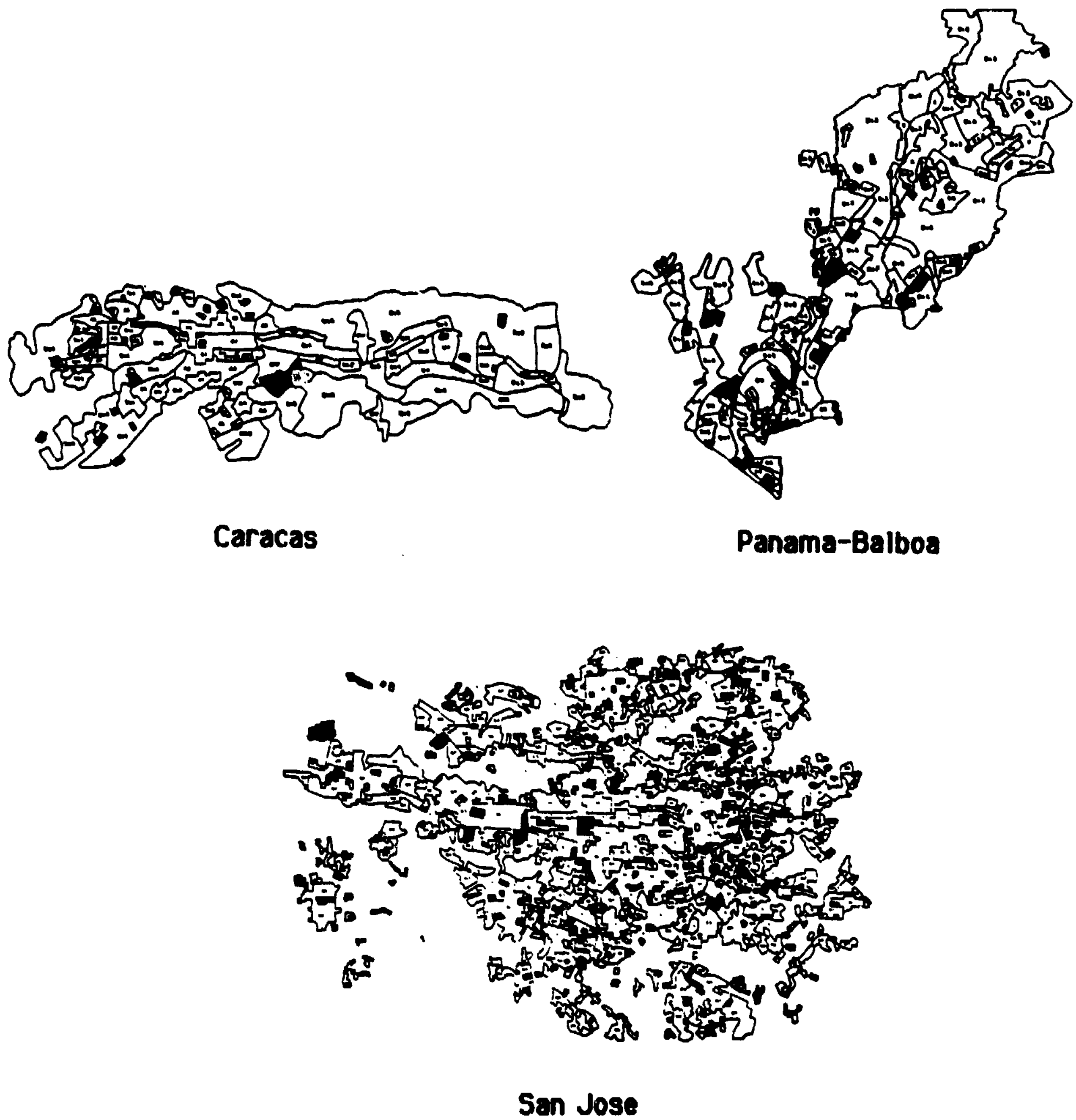


Figure 49. Urban terrain zone Do6 (administrative/cultural): Latin American cities.

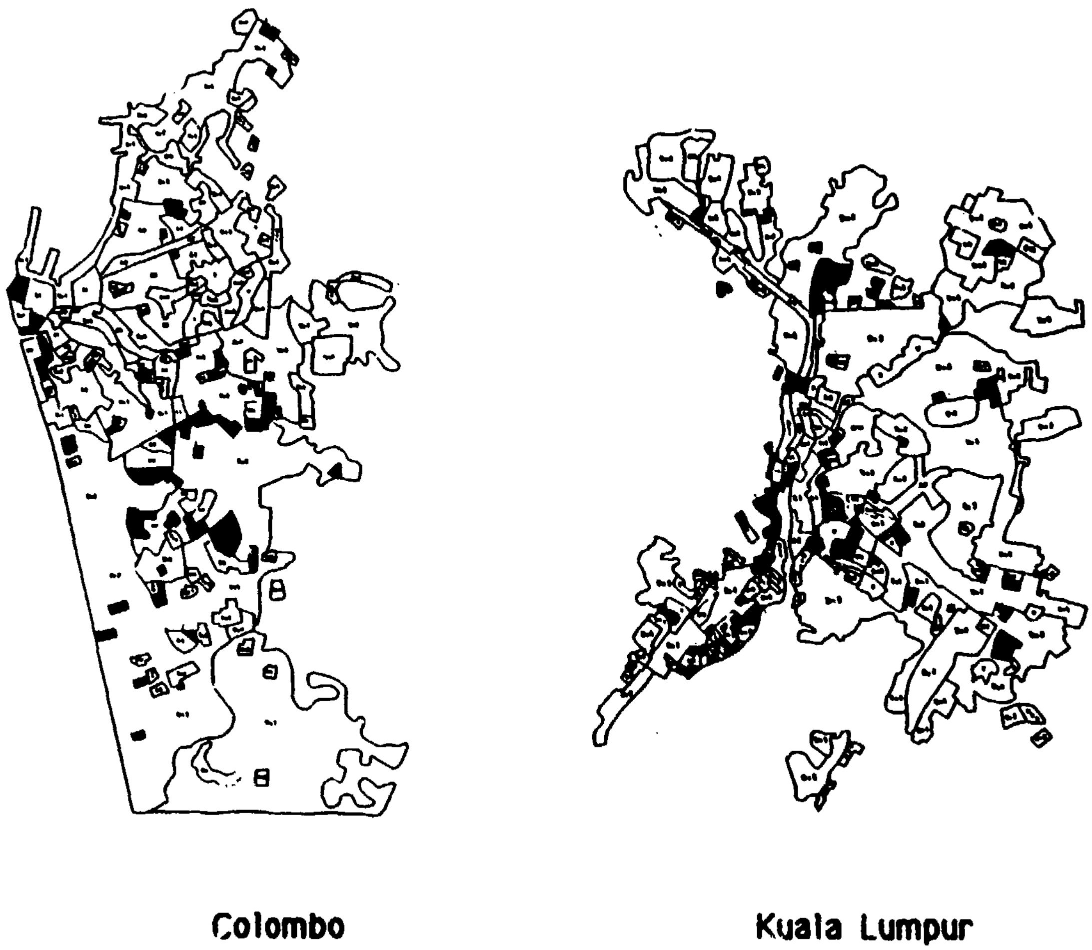


Figure 50. Urban terrain zone Do6 (administrative/cultural): Asian cities.

In addition to an even spatial distribution, these Do6 occurrences are often fairly small in area, a school campus ground for instance, or a cluster of administrative buildings. Some are large, however, as is seen in some permanent military installations lying within urban areas. The extensive grounds of university campuses or major hospitals with attending buildings are other examples.

Perhaps most important to the process of allowing for the encountering of various environments in MOUT planning is that administrative/cultural zones are universal in cities throughout the world. Not all cities have some of the other zones, such as shanty towns, for instance. But, all societies have need for places to house their administrative functions and all have cultural and other institutions that require homes. Because these functions are administered either by governmental or large private organizations, there is the opportunity to acquire fairly large parcels of land and to place planned, orderly sets of buildings (with attendant open area in between) on them.

European cities provide a good example. In Vienna, significant space is devoted to this phenomenon in many parts of the city. The only exceptions are the heart of the Altstadt--where space is limited for all functions--and the industrial/storage areas where the occurrence of administrative/cultural functions would be incompatible. The city's famous Ringstrasse area--built on ground cleared when the old city wall was razed--is the site of several Do6 developments. Helsinki shows about the same pattern with its large planned administrative area adjacent to the core. Stuttgart has a similar pattern with a significant area of public buildings and open space lying just at the edge of the downtown area. Braunschweig has somewhat smaller occurrences of the same situation.

The Mediterranean cities display about the same pattern. Tel Aviv-Yafo--being a product of modern city planning--has such units quite evenly dispersed. The large one in the eastern part of the city, however, is a military installation. Tunis has some small instances in the older (eastern) section of the city, some larger ones in the northern suburban section, and one very large area of hospitals and related medical facilities in the western, central part of the city. The pattern in Athens-Piraeus is the usual dispersed one. Beirut shows a similar pattern; the large area in the northwestern part of the city is the campus of the American University.

The same general pattern is observed for the Latin American cities. The large area in central Caracas is a university campus. Panama-Balboa has a fair number of occurrences of Do6. Some are in planned Balboa and some in the main part of the city. San Jose has a wide number of small instances in churches (always with accompanying plazas) and both public and secular educational institutions.

In Asia, the pattern is the same. Both example cities are product of British colonial developments, ones that favored the founding of administrative/cultural institutions with their accompanying forms. Colombo has some large ones in the suburban area (central and south) but few in the crowded residential and commercial area in the northern part of the city.

The comparisons described and analyzed above are but examples of similar relationships observed from city to city for all urban terrain classes. Individual thematic maps of each class for every city may be consulted (see thematic maps in Appendix C).

CHARACTERISTICS OF BUILDINGS WITHIN TERRAIN ZONES

The nature of buildings that occupy urban terrain zones is of key importance to MOUT. Knowledge of such features as the type of construction, building height, and exterior wall surface texture is invaluable. In addition, by knowing the distribution of types of buildings, other characteristics important to military operations may be inferred. Examples are lines of sight, fields of fire, possibilities for maneuver, locations for deployment of weapons of various types, and observation points.

Most of the zones in cities everywhere are largely homogeneous as to type of buildings and their characteristics. Certainly, the residential classes (comprising the most area in any city) tend to be homogeneous. The reason is that the mode of construction and setting of buildings within a zone follows local construction practice. Thus, for example, the single family detached housing of residential areas of a particular city will nearly all be made of brick, wood, or whatever the local common construction form may be. Change of construction form has taken place at certain times when either some new technology was introduced or conditions for importing exotic materials and techniques became more favorable. An example is the conversion from brick construction to framed construction. In a typical case, a large older area of residential buildings made of brick occupies a section of a city. The same city will almost always have newer sections, constructed since modern construction technology came to the country, where virtually all of the buildings are constructed with reinforced framed concrete construction. The result is that a city has several morphologically different residential areas. One area has one type of construction, one has another but each has a high degree of homogenity.

Only when such areas undergo conversion building by building does much mixing occur. A typical case is an industrial/storage area that has such a degree of permanence that old masonry buildings are razed within a zone and are replaced, singly, by framed construction buildings.

Building Construction Types: Terrain Zones

The actual occurrence of building construction types and building height is recounted in the following material. Methods employed to acquire the data consisted of devising a sampling frame with its size based on the proportional representation of each urban terrain zone to permit equitable comparison. The proportion that each urban terrain zone class formed of the total was noted (from Table 4). Then, the sample size was decreed to be 10 buildings for each percentage point. For example, the A2 zone, forming 3.6 percent of the aggregate, called for observing and classifying 36 buildings within A2 zones for each city. The points within the zones to be sampled were selected at random (by dropping a handful of thumb tacks on the map and scoring the buildings touched by the tack points).

The actual figures were then converted to percentages for making relative comparisons.

Measurement of building types (Table 6) made the distinction between mass and framed construction. Actual figures are given for most of the zones of the city: sums and percentages are presented for each region and for the total of each urban terrain zone.

Prevailing types were then grouped. Figure 51 lists, in rank order, terrain zones where mass construction dominates: Figure 52 ranks zones where framed buildings exceed 50 percent of all structures in a zone.

Several separate reasons can be cited to explain why mass construction dominates in some zones (Figure 51). In rank order—as seen on the graph—are

- Dc7 (the engulfed agricultural village) has a high proportion of mass buildings partly because of having been built prior to the time of modern framed construction and partly because structures are low-rise.

- A3 (apartments and row houses). Again, the attached form zones are generally old and, in this case, are also low-rise.

- Dc3 (houses, close-set). These structures are often built with mass construction although the Mediterranean area is an exception.

- Dc2 (apartments, close-set). Almost exactly the same pattern (as the Dc3 zone) is seen.

- Do3 (houses, open-set). Traditionally, Do3 stuctures in many parts of the world were made with mass construction but large number of new, framed structures, especially in the Mediterranean, Asia, and Latin America have reduced this dominance.

Conversely, another set of equally applicable reasons can be cited to explain the domination of the remaining terrain zones by framed structures (Figure 52). With the exception of the Do2 modern apartment zone, all are nonresidential in character. One important reason for this is the greater inherent adaptability of framed structures in allowing subdivision of a building's interior space into the varying sized units required by a wide variety of nonresidential users. Specific reasons, per zone, are

- Dc5 (outer city) is composed entirely of framed light-clad buildings. Only structures of this type would be suitable for the commercial use for which they are designed.

- Do4 (truck-related industrial/storage). Frames are dominant here partly because these zones are of recent vintage and partly because framed buildings, especially the thin-walled structures, are cost-beneficial for many industrial/storages uses.

- Do2 (apartments, open-set). So many units of this type use framed structures as being the preferred means for constructing high-rise (more than five stories) structures.

Table 6

Building Types: Major Terrain Zones

Cities	Terrain Classes A2 Mass	A2 Framed	A3 Mass	A3 Framed	A4 Mass	A4 Framed
EUROPE						
Helsinki	26	10	134	10	7	6
Braunschweig	-	-	-	-	-	-
Stuttgart	28	9	133	11	7	7
Vienna	32	3	141	3	9	5
Subtotal	86	22	408	24	23	19
Percent	80	20	94	6	55	45
MEDITERRANEAN						
Athens-Piraeus	4	32	14	130	2	12
Tel Aviv-Yafo	2	34	10	134	3	11
Beirut	3	33	27	117	3	11
Tunis	8	28	94	50	6	7
Subtotal	17	127	145	441	15	41
Percent	12	88	25	75	27	73
ASIA						
Colombo	-	-	130	14	9	5
Kuala Lumpur	17	19	125	19	6	8
Subtotal	17	19	255	33	15	13
Percent	47	53	89	11	54	46
LATIN AMERICA						
San Jose	12	24	138	6	9	5
Panama-Balboa	-	-	36	108	5	9
Caracas	-	-	74	70	5	9
Subtotal	12	24	248	184	19	23
Percent	33	68	57	43	45	55
GRAND TOTAL	132	192	1056	682	72	96
PERCENT	41	59	61	39	43	57

(continued)

Table 6 (Continued)

Building Types: Major Terrain Zones

	Terrain Classes							
	Do2		Do3		Do4		Do6	
Cities	Mass	Framed	Mass	Framed	Mass	Framed	Mass	Framed
EUROPE								
Helsinki	27	49	82	0	22	20	48	10
Braunschweig	49	29	82	0	21	21	21	38
Stuttgart	45	31	82	0	9	33	17	41
Vienna	51	25	82	0	28	14	56	2
Subtotal	172	134	328	0	80	88	142	91
Percent	56	44	100	0	48	52	61	39
MEDITERRANEAN								
Athens-Piraeus	0	76	16	56	0	42	8	50
Tel Aviv-Yafo	0	76	9	73	0	42	0	58
Beirut	0	76	-	-	0	42	10	48
Tunis	2	74	24	58	0	42	28	30
Subtotal	2	302	49	187	0	168	46	186
Percent	1	99	21	79	0	100	20	80
ASIA								
Colombo	58	18	37	44	2	40	38	20
Kuala Lumpur	0	76	32	50	0	42	30	28
Subtotal	58	94	69	94	2	82	68	48
Percent	38	62	42	58	2	98	59	41
LATIN AMERICA								
San Jose	0	76	70	12	0	42	37	21
Panama-Balboa	0	76	17	65	0	42	33	25
Caracas	0	76	14	68	0	42	20	38
Subtotal	0	228	101	145	0	126	90	84
Percent	0	100	41	59	0	100	52	48
GRAND TOTAL	232	758	546	426	82	464	346	408
PERCENT	23	77	56	44	15	85	46	54

(continued)

Table 6 (Continued)

Building Types: Major Terrain Zones

Cities	Terrain Classes Dc2 Mass	Dc2 Framed	Dc3 Mass	Dc3 Framed	Dc4 Mass	Dc4 Framed	Dc5 Mass	Dc5 Framed	Dc6 Mass	Dc6 Framed
EUROPE										
Helsinki	90	29	-	-	45	41	-	-	-	-
Braunschweig	115	9	183	0	45	41	-	-	-	1
Stuttgart	108	11	183	0	11	75	-	-	3	1
Vienna	116	3	183	0	75	11	0	3	3	1
Subtotal	429	52	549	0	176	168	0	3	9	3
Percent	89	11	100	0	51	49	0	100	75	25
MEDITERRANEAN										
Athens-Piraeus	6	113	5	178	4	62	-	-	-	-
Tel Aviv-Yafo	0	119	13	160	7	79	-	-	2	2
Beirut	12	107	21	162	5	81	-	-	-	-
Tunis	27	92	72	111	10	76	1	3	-	-
Subtotal	45	431	111	611	26	318	1	3	2	2
Percent	9	91	15	85	8	92	25	75	50	50
ASIA										
Colombo	75	44	140	43	56	30	-	-	-	-
Kuala Lumpur	70	49	110	31	21	65	0	3	-	-
Subtotal	145	93	250	74	77	95	0	3	-	-
Percent	61	39	77	23	45	55	0	100	-	-
LATIN AMERICA										
San Jose	115	4	145	38	46	40	-	-	-	-
Panama-Balboa	60	59	150	33	40	46	0	3	-	-
Caracas	70	49	48	115	31	55	0	3	-	-
Subtotal	245	112	343	186	117	141	0	6	-	-
Percent	69	31	65	35	45	55	0	100	-	-
GRAND TOTAL	864	688	1283	871	396	722	1	15	11	5
PERCENT	56	44	59	41	35	65	6	94	69	31

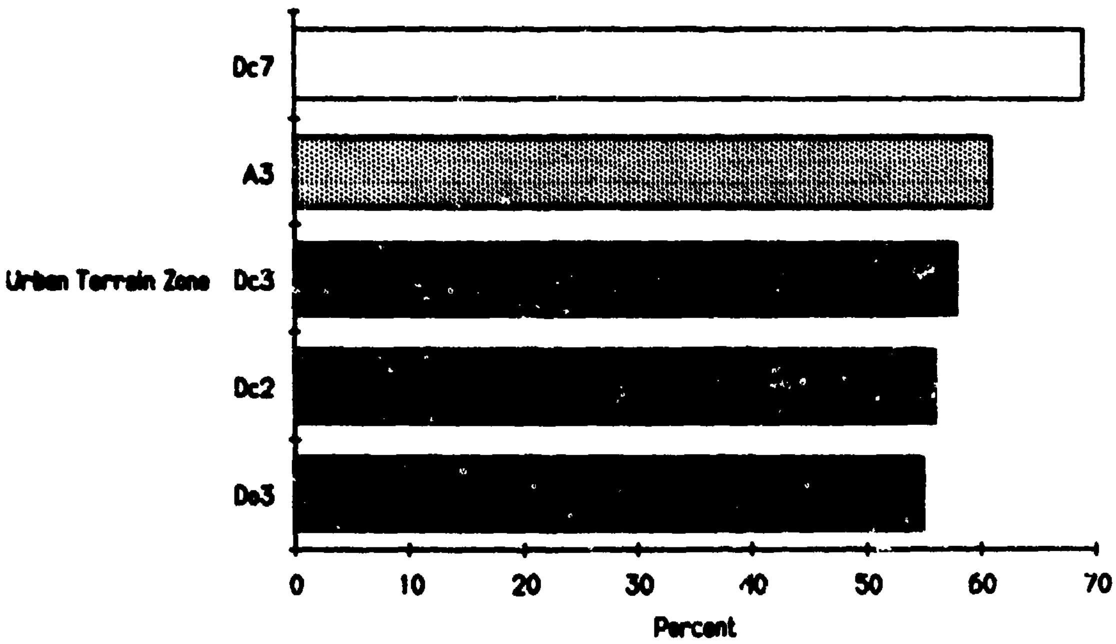


Figure 51. Urban terrain zones: Mass construction dominant.

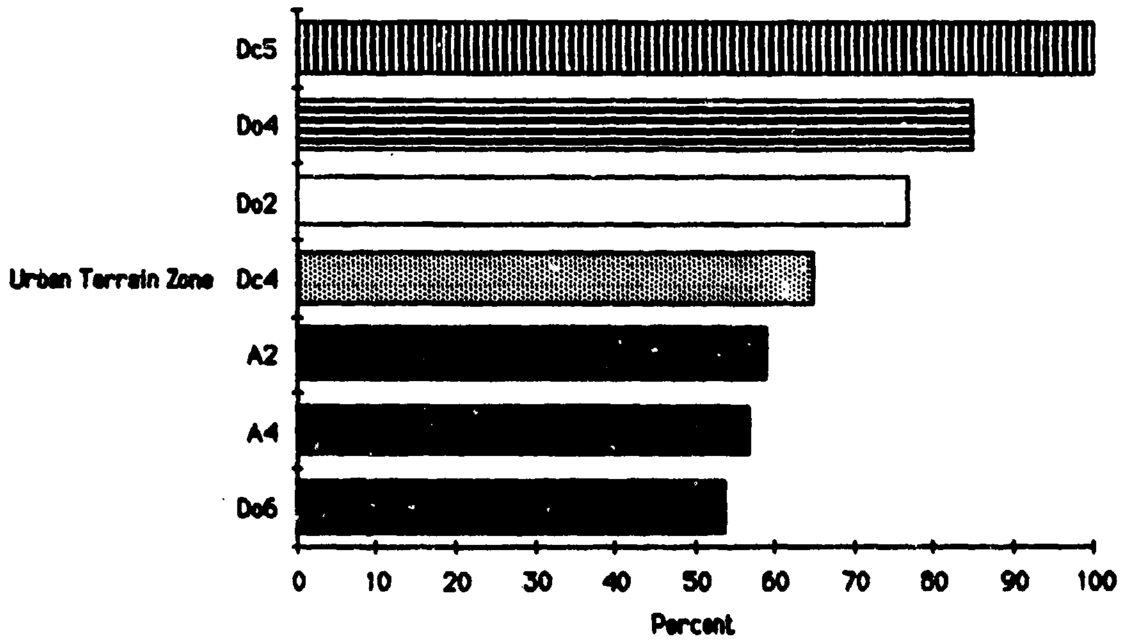


Figure 52. Urban terrain zones: Framed construction dominant.

● Dc4 (railroad and dock-related industrial/storage). While this zone has numerous older mass construction buildings, frames form the majority. As with the truck-related class, many industrial/storage applications make good use of the properties of framed structures.

● A2 (apartments, hotels in the core periphery). The figure of 59 percent framed structures in this zone indicates how far the transition from mass construction has progressed. This process, as expected, is much further along in the more recently developed cities and lagging in Europe.

● A4 (full urban form industrial/storage). This zone has historically had a high proportion of mass buildings. The framed structures majority, in the aggregate, comes largely from the more recently developed cities.

● Do6 (administrative/cultural). The bare majority of frames stems mostly from the large numbers of recent institutional construction. Institutions, by their very longevity, have large numbers of older, mass-constructed buildings.

Building Height: Terrain Zones

A measurement of building heights for each zone (not all cities have all zones) along with a statement of observed dominant height (in number of stories) was made for each of the 13 studied cities (data appear in Appendix B).

Some zones are naturally low in profile, e.g., houses and truck-related industrial/storage structures. In other instances, some cities are, on the whole, taller. Generally, large cities have high enough land values to make profitable the multiplication of surface space by high-rise construction. Sometimes, land values rise (making tall buildings the only viable alternative) due to physical lack of suitable building places. Especially tall cities are Caracas (large, rapidly growing and with a finite amount of level land); Kuala Lumpur (quickly filling a need for high-rise offices and hotels to serve a rapidly developing economy); Athens and Beirut with their large populations and limited optimally located buildable space; Tel Aviv as the leading commercial center of Israel; and parts of Panama City in its rapid growth areas.

Low-profile cities are those of Europe plus slow-growing Colombo, San Jose, and Tunis. Each has, however, as the table indicates, some locally tall buildings.

On the aggregate, the tallest urban terrain zones for all cities are

A1, the core
A2, the core periphery
A4, the urban form industrial/storage area located near the core
Dc1, the urban redeveloped core area
Dc5, outer city
Do2, open-set apartments

Necessarily, or customarily, low-height zones are:

A3, apartments and row houses
A5, old commercial ribbons
A9, old core, vestigial
Dc2, apartments, close-set
Dc3, houses, close-set
Dc4, railroad and dock-related industrial/storage
Dc7, engulfed agricultural villages
Dc8, shanty towns
Do1, shopping centers
Do3, houses, open-set
Do4, truck-related industrial/storage
Do5, new commercial ribbons
Do6, administrative/cultural

Building height, as a measure, has some correlation with building type (examined in the previous section). With only very rare exception, all buildings over five stories tall are framed structures owing simply to the infeasibility of using mass construction methods for all building construction. A high proportion of buildings shorter than five stories are also framed structures. This situation is especially the case in Asia, the Mediterranean, and Latin America.

The zone where the greatest degree of conversion can be expected is the core area of a city. Because the land of these areas is constantly of such high value, there is impetus to replace old building stock with new (the direction usually being to taller structures able to take advantage of the high-cost land). The following data--derived from measurements taken in the field with method described earlier--provides a detailed examination of the core areas (Urban Terrain Zone A1) for the studied cities. Data are given for 1) building type; 2) building height; and 3) exterior wall texture.

Urban Terrain Zone A1: Building Types

The basic types of construction were observed and recorded in the field for sample areas within the A1 zone of each city. Notation was made as to whether buildings were mass construction, framed heavy-clad or framed light-clad (see data in Table 7 and the graph, Figure 53).

The total figures (for all the cities) show that mass construction accounts for 39.7 percent. Framed structures (both heavy- and light-clad combined) form the balance of the total with 60.3 percent. Heavy-clad structures account for 10.1 percent while framed light-clad structures form 50.2 percent. Each region varies.

Looking first at mass construction, European and Asian cities have figures above the average: 47.7 percent in Europe and 52.3 percent in Asia. Mediterranean cities are slightly below average with 36.9 percent while Latin American cities are considerably lower at 22.6 percent. As stated earlier, the rate of economic growth and development plays a

Table 7

Urban Terrain Zone A1
Building Type: Number and Percent

Cities	Mass No.	Mass %	Framed Heavy-Clad No.	Framed Heavy-Clad %	Framed Light-Clad No.	Framed Light-Clad %	Total No.
EUROPE							
Helsinki	42	46.2	12	13.2	37	40.7	91
Braunschweig	54	44.3	2	1.6	66	54.1	122
Stuttgart	16	23.5	5	7.4	47	69.1	68
Vienna	83	64.8	18	14.1	27	21.1	128
Subtotal	195		37		177		409
Average		47.7		9.0		43.3	
MEDITERRANEAN							
Athens-Piraeus	38	25.7	16	10.8	94	63.5	148
Tel Aviv-Yafo	(No A1 Zone)						
Tunis	65	49.6	22	16.8	44	33.6	131
Subtotal	103		38		138		279
Average		36.9		13.6		49.5	
ASIA							
Colombo	71	62.9	12	10.6	30	26.5	113
Kuala Lumpur	53	42.7	7	5.6	64	51.6	124
Subtotal	124		19		94		237
Average		52.3		8.0		39.7	
LATIN AMERICA							
Panama-Balboa	26	35.1	4	5.4	44	59.5	74
San Jose	28	35.4	7	8.9	44	55.7	79
Caracas	18	10.8	19	11.4	129	77.7	166
Subtotal	72		30		217		319
Average		22.6		9.4		68.0	
GRAND TOTAL	494		124		626		1244
AVERAGE		39.7		10.0		50.3	

Height--In Number of Stories

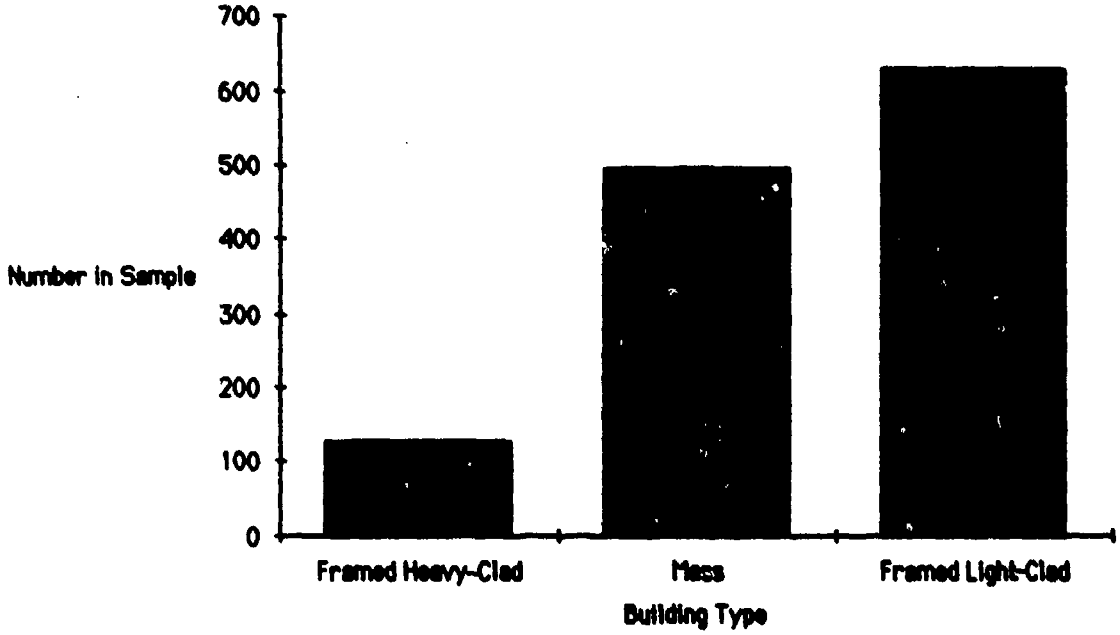


Figure 53. Urban terrain zone A1: Building types.

significant role. Cities in those countries that have developed rapidly and whose urban complexes date mainly from the post-World War II period can be expected to have low proportions of mass construction buildings. Older cities in stable countries (Vienna is the most well-developed example) retain many of their older mass structures with relatively little newer framed construction except for necessary rebuilding. Many German cities, of course, have had their downtowns very largely rebuilt in postwar times. A city like Frankfurt am Main is an excellent example, going as it did from ruins to skyscrapers in two decades.

For the framed heavy-clad class, there is relatively little deviation from one region to another. This represents mainly the recent construction of large downtown buildings that had prevailed in the twenties and thirties as cities everywhere first began erecting high-rise structures. Examples of these are seen in 11 of the cities. The buildings have remained fairly well untouched in the modern era as they are fairly large, and therefore efficient structures and are no such obvious candidates for replacement as are the usually smaller, less efficient brick buildings. Also, their survival rate during the war was greater than that of the easily toppled (and incinerated) brick structures.

The case for the framed light-clad structures is virtually the inverse of that for brick buildings. Indeed, the framed light-clad buildings have almost everywhere been constructed on land made available by razing brick buildings; the process was "forced" in the case of many war-damaged cities. (The process in U.S. cities has been economically induced). Europe, while it has many framed light-clad buildings, stands below the aggregate figure. Of the individual cities, note that Stuttgart and Braunschweig (both heavily damaged during the war) have extraodinarily high percentages. In the Mediterranean cities, Athens-Piraeus has a high development. If Tel Aviv-Yafo actually had an A1 zone, rather than simply some string commercial streets among apartment zones, the buildings would be framed light-clad as are virtually all buildings in this rapidly developing city. The Asian cities are two opposites. Colombo is economically backward with only one incipient new area of "light-clads." Kuala Lumpur, by contrast, is the epitome of rapid growth in a dynamic economy where large numbers of new, high-rise framed light-clad buildings are currently under construction.

Urban Terrian Zone A1: Building Heights

Building height is a valuable and interesting fact for MOUT planners. First, the distribution of height of buildings is an indication of the amount of floor surface area, considering that each floor is another replication of ground surface area. Thus, in the simplest form, the ground surface is multiplied several times and thus provides that much more space for deploying defenders, weapons, and other military components.

Building height is also a rough indication of type of construction, considering the practical limit of five stories for mass construction buildings and the virtual lack of limit to the height of framed buildings. Generally, there are very few mass construction structures taller than five stories and few framed structures shorter than three stories.

For the purposes of analysis (see Table 8 and Figure 54), discrete floor heights are given for buildings ranging from three stories through seven stories, the most common heights in core areas of cities. Beyond this (eight or more stories), building heights vary widely. A grouping of such structures covers a class that ranges from eight through thirty stories.

Of the shorter structures, 24.0 percent of buildings, in the aggregate, are at the three-story height, 20.4 percent are four stories tall, and 15.6 percent are 5 stories in height. In other words, 60 percent of all buildings in this core area zone are three, four, and five stories tall. Of the remainder, the largest group is the top class (eight and above) accounting for 22.0 percent of the total. This means that just less than one-quarter of all of the buildings in the A1 zones are what might be called "high-rise" while the remainder forms a relatively low profile.

Regional deviations from the aggregate are readily explainable. Looking first at the three-story buildings, the European cities record relatively low proportions (with the exception of Helsinki). The ready answer is that such relatively low buildings are inefficient users of scarce downtown urban space; most have long since been replaced by taller buildings. Of the Mediterranean cities, Athens-Piraeus has long since had such critical need for surface space that the average building height has had to be fairly great. Tunis, however, is still pretty much a sleepy backwater and has shown little inclination to replace low buildings with taller structures. The same holds true for Colombo, where many of the shorter buildings remain essentially as they have for many decades. Kuala Lumpur is the curious case having still both large areas of the older, less efficient "colonial" structures and sections of the most modern of new framed high-rise structures. Of the Latin American cities, Panama-Balboa is a city with a generally low profile while Caracus--although it has many remnant low structures--has large areas of dramatic new framed light buildings.

Going upward in height, to the four-, five-, and six-story buildings, we see the archetypal European city character. Structures of this height attain the maximum number of floors practical without provision of elevator service. Such buildings are efficient users of expensive urban land. Semblances of the same pattern show up in all of the regions with the exception of Caracas, which has either low structures or the very tall, new skyscrapers.

Table 8

Urban Terrain Zone A1
Building Heights: Number and Percent

Cities	Height--In Number of Stories												Total
	3		4		5		6		7		8		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
EUROPE													
Helsinki	15	21.4	17	24.3	20	28.6	8	11.4	6	8.6	4	5.7	70
Braunschweig	6	9.5	22	34.9	23	36.5	10	15.9	2	3.2	-	-	63
Stuttgart	4	5.5	36	49.3	18	24.7	6	8.2	5	6.8	4	5.5	73
Vienna	3	2.4	6	4.8	33	26.2	65	51.6	4	3.2	15	11.9	126
Subtotal	28		81		94		89		17		23		332
Average		8.4		24.4		28.3		26.8		5.1		6.9	
MEDITERRANEAN													
Athens-Piraeus	3	3.5	9	10.5	7	8.1	8	9.3	4	4.7	55	63.9	36
Tel Aviv-Yafo	(No A1 Terrain Zone)												
Tunis	39	30.5	35	27.3	26	20.3	9	7.0	7	5.5	12	9.4	128
Subtotal	42		44		33		17		11		67		214
Average		19.6		20.6		15.4		7.9		5.1		31.3	
ASIA													
Colombo	42	38.5	23	21.1	7	6.4	9	8.3	4	3.7	24	22.0	109
Kuala Lumpur	41	47.1	3	3.4	13	14.9	4	4.6	1	1.1	25	28.7	87
Subtotal	83		26		20		13		5		49		196
Average		42.3		13.3		10.2		6.6		2.6		25.0	
LATIN AMERICA													
Panama-Balboa	28	39.4	27	38.0	5	7.0	1	1.4	1	1.4	9	12.7	71
San Jose	31	39.2	[illegible]	25.3	7	8.9	7	8.9	7	8.9	7	8.9	79
Caracas	41	25.6	17	10.6	5	3.1	13	8.1	8	5.0	76	47.5	160
Subtotal	100		64		17		21		16		92		310
Average		32.3		20.6		5.5		6.8		5.2		29.7	
GRAND TOTAL	253		215		164		140		49		231		1052
AVERAGE		24.0		20.4		15.6		13.3		4.7		22.0	

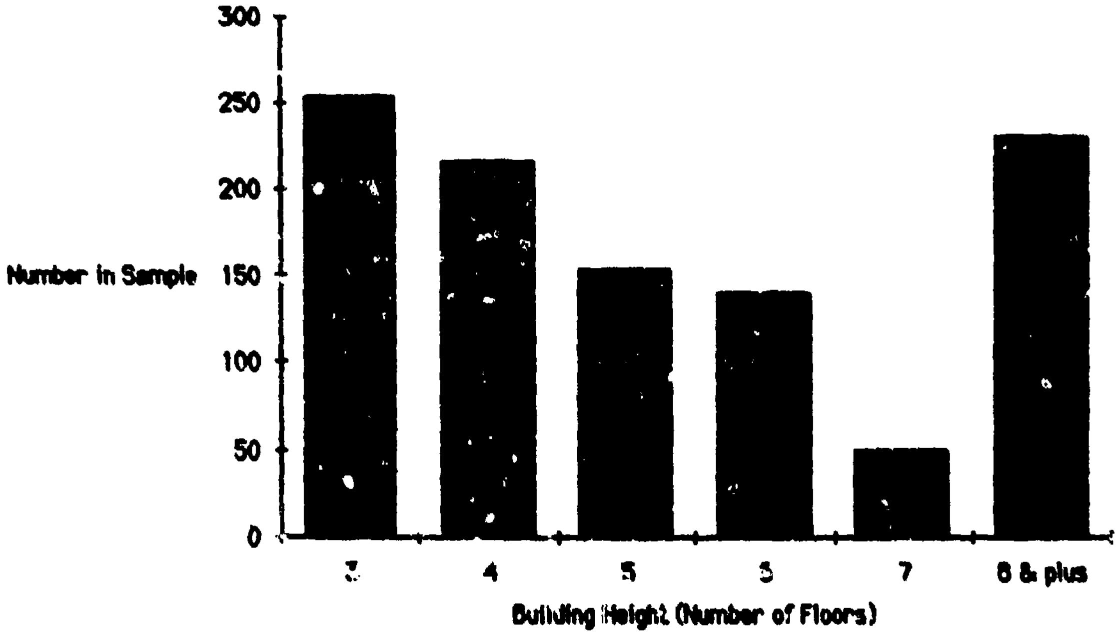


Figure 34. Urban terrain zone A1: Building height.

At the higher end of the scale, Europe is the region (within the study cities) with the relatively fewest tall buildings. Part of this is attributable to the clinging to older, classical forms of design. Common in a West German city are successive blocks of recently constructed, framed light-clad buildings attaining heights of only some five stories. By way of contrast, Athens-Piraeus has a considerable number of buildings in its A1 area that are at or above eight stories; Kuala Lumpur and Caracas have skylines punctuated by tall skyscrapers.

Urban Terrain Zone A1: Building Surface Texture

The texture of the exterior surface of buildings is significant to MOUT considerations of the city because of the possible effect it has on the behavior of warheads fired at buildings. Surface textures very from smooth, as with glass and composition, to very rough, as with brick and stone.

The nature of texture is a product of several factors. An obvious one is architectural. The architect prescribes a certain texture in order to achieve a desired effect in the appearance of the building. This decision, however, is tempered--as are all choices in building design--by cost, characteristics of the building, and the building's intended function. An example of the interaction of some of these can result in an exposed surface of decorative brick veneer on a framed structure. Or, a veneer of stone might be selected to cover a brick-constructed building. Or, a framed light-clad building may have a "skin" of glass.

The classes recorded require explanation. The class entitled Brick indicates exposed, laid brick and is usually of the common size (some 11 by 23 centimeters); the surface is generally that of common bricks. Stone is mostly decorative and may have either a polished or an unpolished surface. Plaster is commonly around 3 centimeters thick and has the usual sand-based texture. Glass is a term used here for buildings with a complete glass "skin." Of course, virtually all the other buildings have windows; the reference to other material is that between the windows. Composition refers to building material of plastic or fiberglass.

Order does exist (see the data in Table 9 and the graph, Figure 55). First, a majority of buildings in the study (some 62.2 percent) are plaster covered The main reason for the builder's choice of plaster is that it is suitable as a cover to protect the mortar of bricks forming the walls (either load-bearing or in-fill) of buildings. It is also easily gives further protection with paint. The percentage is so high (higher than the proportion of mass construction [mostly brick]) because plaster is used both to cover the bricks of mass construction buildings and to cover the terra-cotta and concrete block "in-fill" walls of reinforced concrete framed structures.

Table 9

Urban Terrain Zone A1
Building Surface Texture: Number and Percent

Cities	Type of Building Surface										Total
	Brick		Stone		Plaster		Glass		Composition		
	No.	%	No.	%	No.	%	No.	%	No.	%	No.
EUROPE											
Helsinki	16	20.8	7	9.1	26	33.8	5	6.5	23	29.9	77
Braunschweig	10	10.0	18	18.9	23	23.0	9	9.0	40	40.0	100
Stuttgart	1	1.3	10	13.0	19	24.6	10	13.0	37	48.1	77
Vienna	-	-	8	6.2	106	82.1	2	1.6	13	10.1	129
MEDITERRANEAN											
Athens-Piraeus	5	7.5	7	10.4	14	20.9	31	46.3	10	14.9	67
Tel Aviv-Yafo	(no A1 Zone)										
Tunis	2	2.2	5	5.6	78	87.6	3	3.4	1	1.1	89
ASIA											
Colombo	7	8.8	2	2.5	61	76.3	4	5.0	6	7.5	80
Kuala Lumpur	8	9.4	4	4.7	44	51.8	16	18.8	13	15.3	85
LATIN AMERICA											
Panama-Balboa	2	2.1	2	2.1	83	85.6	3	3.1	7	7.2	97
San Jose	2	2.5	3	3.8	65	82.3	5	6.3	4	5.1	79
Caracas	3	2.0	3	2.0	121	81.2	9	6.0	13	8.7	149

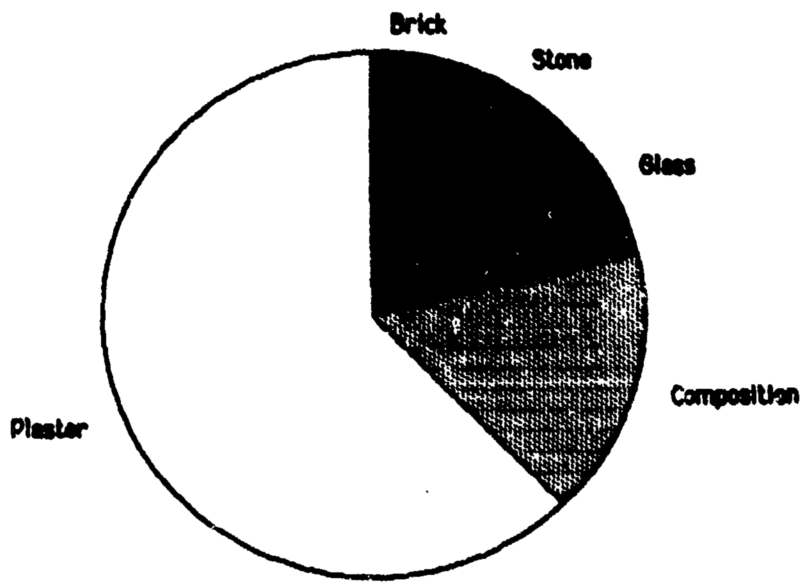


Figure 55. Urban terrain zone A1: Building surface textures.

Referring to the total figures for other textures, we see that only a small percentage (5.4 percent) has exposed brick, and a similar figure (6.7 percent) has exposed stone (most of which is veneer). The remaining classes, glass and composition (found only on framed buildings), form 9.4 percent and 16.2 percent, respectively, of all buildings sampled.

An examination of the regional patterns shows that in some cases there is little deviation from the aggregate figures while in others there is considerable difference. Showing little difference from place to place is the incidence of occurrence of brick and stone. Plaster, on the other hand, shows rather broad regional difference. Some of this is due to basic differences in construction type. For instance, the high proportion of plastered buildings in Vienna (in the A1 area) is related to its high proportion of brick structures virtually all of which are plastered. Conversely, Athens-Piraeus has a low figure thanks to that zone's high proportion of framed buildings. The areas with consistently high proportions of plaster-covered buildings are found in Asia and in Latin America. Both areas have large numbers of plaster-covered framed buildings and, in addition, a fair number of plastered mass structures. The figures for glass structures is fairly even everywhere except for Athens with its high proportions of framed structures. The greatest deviations of composition surfaces is seen in Europe and especially in the German cities of Braunschweig and Stuttgart. Along with Finland, Germany uses its high technology level to produce a wide variety of building materials. Advanced architectural designs add to the variety of materials selected.

CONCLUSIONS

- Though many conditions vary widely for cities around the world, a positive sense of order and replication exists for the urban terrain zones of these cities.

- Urban terrain zones and building types of these cities are readily classified in accordance with a universal scheme.

- The study cities are remarkably similar in the physical characteristics of their building and terrain zones despite visual differences in architecture.

- Interpreting remotely sensed imagery, supported by "ground truth" observations, is a valid method of acquiring highly detailed data.

- Field observations indicate that the principles concerning MOUT usage of buildings (developed in Ellefsen, Carlson, Thein, Milligan, Lein, & Kanemoto, 1981) are applicable to study cities.

- The urban terrain zones delimited in the study are near the optimum level of generalization to serve the needs of a variety of MOUT studies.

- Variations in cities from region to region are caused, to a considerable degree, by differences in level of economic development and cultural preferences.

● Development of a spatial model can be achieved by expanding and using the single urban terrain zone thematic maps. Such a model has a high potential value for future MOUT studies.

● Variations in cities from region to region are caused, to a considerable degree, by differences in level of economic development and cultural preferences.

● The extensive spatial expansion of cities throughout the world in the last three decades has significant ramifications for MOUT. One is the greatly increased use of reinforced concrete framed construction in all parts of cities. This is only one expression of the pronounced trend to using even lighter construction. These structures commonly use terra-cotta brick as in-fill between the columns and beams (Figure 56). Another is the construction of such related urban terrain zones as detached, high-rise apartments, truck-related industrial/storage zones, and shopping centers. These have the effect of producing a somewhat sharper edge to the periphery of the city than is the case with unplanned incremental expansion composed primarily of houses.

RECOMMENDATIONS

● MOUT planners should develop a data base (containing information on terrain zones, buildings, etc.) for a large number of international cities where threat situations could occur. Such a base would be useful both to general theoretical studies and to the development of a discrete inventory.

● Develop a general spatial model of the urban terrain zones of cities with variations of the model for the different regions.

● Prepare contingency planning for the new type of features encountered in the ever expanding peripheral areas of cities, the region loosely and misleadingly referred to as the suburbs.

● The data acquired and the knowledge gained of the characteristics of the MOUT environment should be transmitted to the entire MOUT community in general and to branches of the U.S. Army in particular.

● The concept of urban terrain zones should be directed to MOUT planners, especially those in combat development and weapons development. These zones could serve as elementary building blocks in the development of specialized techniques and variations of weapons. The MOUT environment is significantly varied from place to place within the city and these differences should be incorporated into thinking about urban combat. The urban terrain should not be treated simplistically. Each urban terrain zone has advantages and disadvantages.

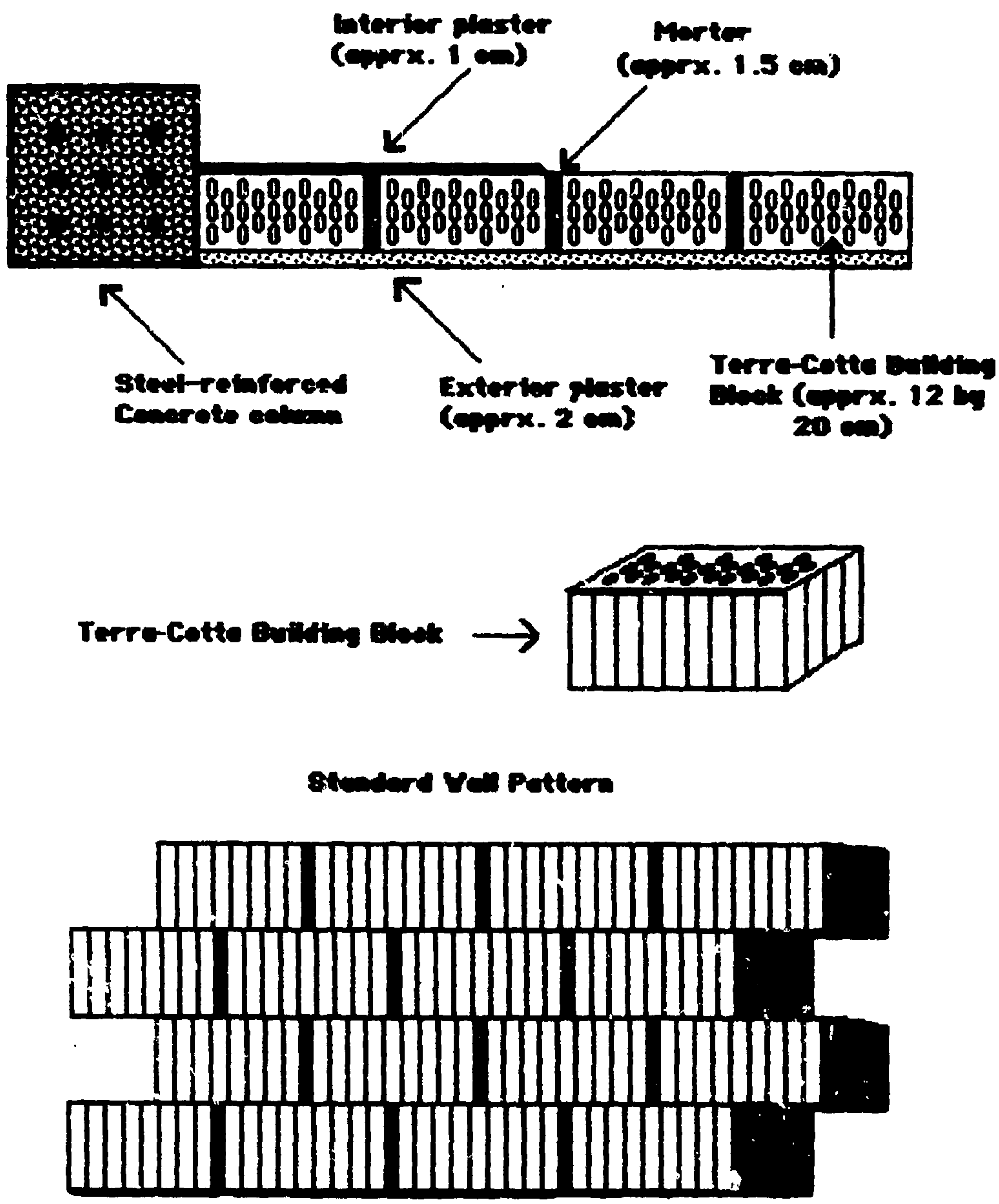


Figure 56. Cross section (top view); typical terra-cotta building block; in-fill wall (framed light-clad construction).

REFERENCES

Department of the Army. (1980). An infantryman's guide to urban combat (Field Manual 90-10-1). Washington, DC: Author.

Ellefsen, R. (1973). Morphological and functional characteristics of built-up urban areas (Technical Report No. 4). Mountain View, CA: GTE Sylvania.

Ellefsen, R. (1983). American Canadian Australian British urban game (ACABUG), urban terrain classification system (TRASANA-TR-63-82). White Sands Missile Range, NM: U.S. Army TRADOC Systems Analysis Activity (TRASANA).

Ellefsen, R., Carlson, A., Thein, B., Milligan, N., Lein, J., & Kanemoto, A. (1981). Urban terrain analysis training aids (Technical Memorandum 14-81). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

Ellefsen, R., Coffland, B., & Orr, G. (1977). Urban building characteristics, setting and structure of building types in selected world cities. Dahlgren, VA: Naval Surface Weapons Center.

Hall, P. (1981). The world cities. New York: McGraw-Hill.

Vance, J. E., Jr. (1977). This scene of man. New York: Harper's College Press.

BIBLIOGRAPHY

Areggar, H., & Glaus, O. (1967). Highrise building and urban design. New York: Praeger.

American-British-Canadian-Australian Armies. (1982). Standardization program, SWP/MOUT report. White Sands Missile Range, NM: U.S. Army TRADOC Systems Analysis Activity (TRASANA).

Bureau of Aeronautics. (1958). Building structure analysis (NAVAER 10-35-637, TM 30-268). Washington, DC: U.S. Naval Photographic Interpretation Center.

Das gefecht der kampftruppen in bebautem gelande. (July, 1977). Koln, FRG.

Department of the Army. (1979). Military operations on urbanized terrain (MOUT) (Field Manual 90-10). Washington, DC: Author.

Ellefsen, R., Kanemoto, A., Milligan, N., & Spring, G. (1980). Geographic characteristics of selected coastal environments. Dahlgren, VA: Naval Surface Weapons Center.

Ellefsen, R., Lein, J., & Milligan, N. (1984). Ground force/aircraft clear lines of sight in urban environments. Dahlgren, VA: Naval Surface Weapons Center.

Ellefsen, R., & Wicks, L. (1979). Characteristics of urban terrain. Dahlgren, VA: Naval Surface Weapons Center.

Gallion, A. B., & Eisner, S. (1975). The urban pattern: City planning and design. New York: Van Nostrand.

Gatz, Donrad. (1967). Curtain wall construction. New York: Praeger.

Hamlin, T. (1952). Forms and functions of twentieth century architecture. New York: Columbia University Press.

Haysler, E. R., & Wood, L. A. (1977). Conventional warfare in an urban environment. Shrivenham, England: The Royal Military College of Science.

Joedicke, J. (1962). Office buildings. New York: Praeger.

Jones, E. (1966). Towns and cities. New York: Oxford University Press.

Mainstone, R. (1972). Discussion, history and philosophy of tall buildings. In Proceedings of the international conference on planning and design of tall buildings. Bethleham, PA: Lehigh University.

Mainstone, R. (1975). Developments in structural form. London: Allen Lane.

Merritt, F. (1962). Building construction handbook. New York: Reinhold.

Muller, P. (1976). The outer city: Geographical consequences of urbanization of the suburbs. Washington, DC: Association of American Geographers.

Rafeiner, F. (1972). Architectural criteria of tall buildings in Germany and Europe in Proceedings of the international conference on planning and design of tall buildings. Bethlehem, PA: Lehigh University.

Sebestyen, G. (1977). Lightweight building construction. New York: Wiley.

Whittick, A. (1974). European architecture in the twentieth century. New York: Abelard-Schuman.

Yorkdale, A. (1972). Masonry building systems in Proceedings of the international conference on planning and design of tall buildings. Bethlehem, PA: Lehigh University.

Yorke, F. R. S., & Giberd, F. (1958). Masterworks of international apartment building design. New York: Praeger.

APPENDIX A

BUILDING CONSTRUCTION TYPES: DEFINITIONS

BUILDING CONSTRUCTION TYPES: DEFINITIONS

Many building classification systems exist. Some emphasize how the structures are used. Others are based on the style of architecture employed None of the existing civilian-based systems however, is suitable for weapons/combat development use. Systems previously used for military purposes have all been designed for such specific purposes as bomb damage assessment or were specifically intended for only a part of the world and do not meet the broad weapons/combat development concerns addressed in this report. Accordingly, introduced here is a system that is based on an important military consideration--the physical properties of buildings and the significance of these in a potential urban combat situation. Further, the system is applicable for urban areas throughout the world.

The system concentrates on the two primary methods used to erect buildings. One method depends on the strength of the walls to hold up the building and its contents. The other method relies upon a frame to bear all the load of a building and its contents.

The distinction is fundamental and is of primary concern to the soldier in the field and military operations on urban terrain. In the first method--the load-bearing walls system--the outer walls (and certain interior walls) of a building must be quite thick in order to give them enough strength to bear loads. The thick walls of these buildings naturally provide more cover than do the thin walls associated with framed construction. Walls of framed construction buildings are referred to as "curtain walls" because they do little more than cover the frame and protect the interior. (In addition, they bind the frame and increase its rigidity, but this factor adds only a modest degree of cover, as from small-arms fire).

The building classification used in this document is based on the fundamental differences between load-bearing wall construction (herein called mass construction) and framed construction with its nonload-bearing walls. The relationship to amount of cover provided by each is reflected in the data given on the crucial features of wall thickness and proportion of windows and doors to blank wall space.

THE BUILDING CLASSIFICATION SYSTEM

The classification system (see Figure A-1) views mass and framed construction as the two solutions available to the architect to solve the problem of how best to provide the type of building required to meet a specified need. The two solutions are mass construction buildings or framed construction buildings. The solution selected depends on the intended use of the building.

Unfortunately, the story is not quite that simple when cities all over the world of varying ages are considered, because architects in the past could not specify the use of such materials as steel and reinforced concrete used today in framed buildings. Most older buildings (roughly pre-1900) used mass construction techniques. So we have, in cities today, large numbers of older mass constructed buildings (usually made of brick) standing alongside more modern construction replacements.

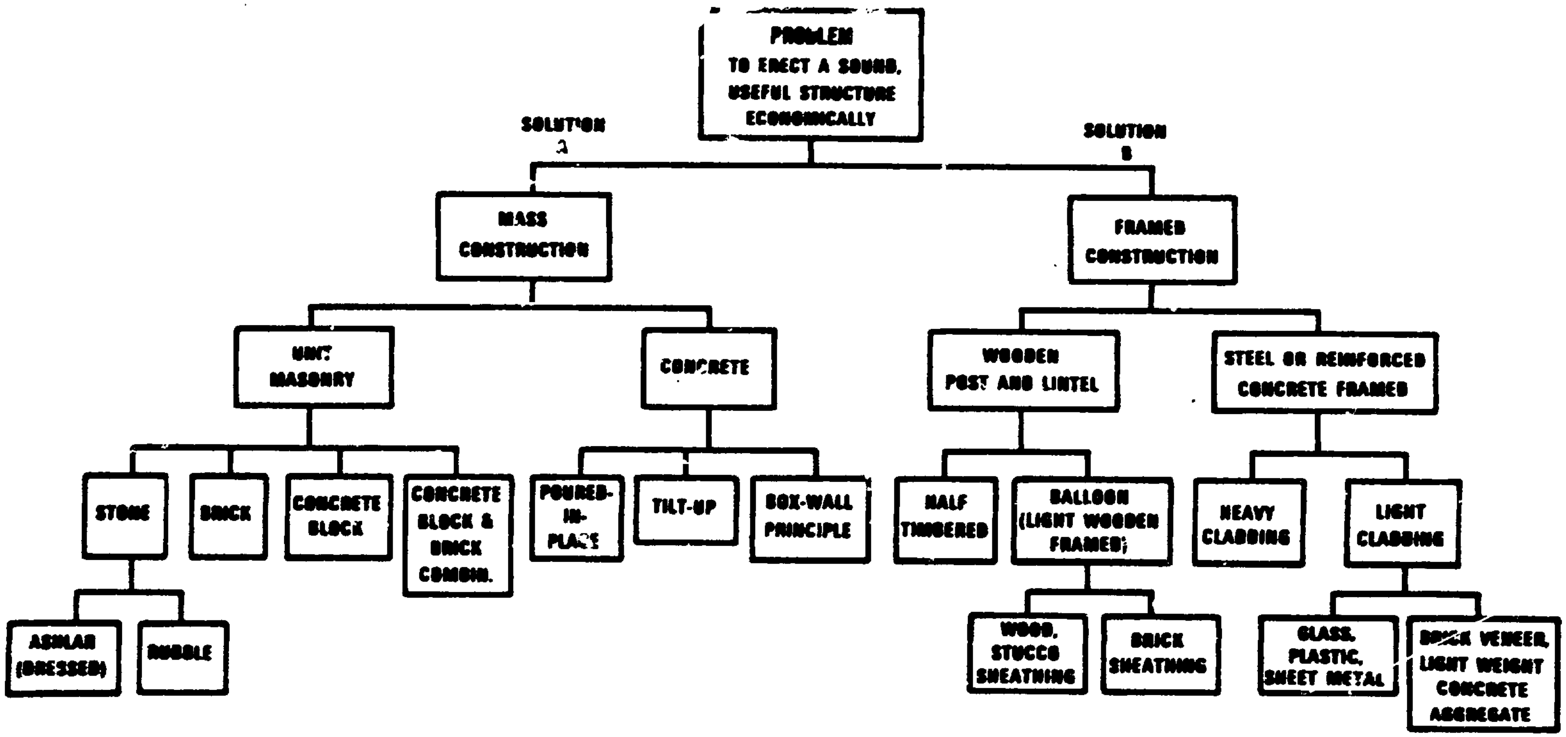


Figure A-1. Universal urban building classification system.

Each of the two major construction types (mass and framed) is subdivided into two parts. Mass construction is broken into unit masonry and concrete. Unit masonry is the method of erecting buildings from individual pieces of stone, brick, or blocks. The method is ancient and simple (the pyramids were built in this way). A house whose walls are made entirely of brick or stone is a good example. Concrete, on the other hand, is a material that can be poured and shaped into walls and other parts of a building that then harden into a durable material.

Framed construction is subdivided into wooden post and lintel as one type and steel or reinforced concrete framed as another type. Wooden framed buildings are a common sight to the American soldier because of the widespread use of wood in housing construction everywhere in the U.S. Steel or reinforced concrete framed construction is seen in cities throughout the world, especially as used for modern high-rise buildings in downtown areas.

Details of each type of construction follow: Full descriptions and drawings of each type appear in Ellefsen, Carlson, Thein, Milligan, Lein, and Kanemoto, 1981. Figures A-2 through A-5 are excerpted from that volume. The following subheadings follow the organization of Figure A-1.

Mass Construction

Unit Masonry

Stone Buildings. Two subtypes of stone buildings exist: rubble stone and ashlar stone. In rubble stone construction, irregularly shaped stones are placed one on top of another to form walls. Large amounts of mortar are used to bind the stones together and to fill up the spaces between them. In ashlar (cut or dressed stone) construction, the stones are shaped into rectangular blocks and stacked to form walls. Because of their tight fit, little mortar is required. The ashlar stone wall is more dense than the rubble stone walls and, because of the binding accruing to the laying of regularly shaped blocks, it has greater strength for its width than does rubble stone.

Rubble stone construction is the cheaper of the two and is seen in general construction where stone is plentiful. It is often used for ordinary houses in such areas; much of the older construction in the Mediterranean Sea area cities is of rubble stone. In these areas, some older commercial buildings are also made of this material.

Ashlar stone construction is used where more money can be invested. Common occurrences are monumental public buildings in large, important cities. Good examples of these buildings are churches, government buildings, and old fortifications. Walls may be up to several feet thick. They are often found in the administrative/cultural urban terrain zone.

Brick Buildings. Viewed in the simplest way, brick is a man-made form of stone (ashlar stone, in particular) made small enough to be handled easily. Forming a thick wall with them requires only that large numbers are laid (and bound by mortar) in such a way that they bind and brace each other for maximum wall strength.

Because the load of the building is borne by the wall, only about one-fourth of the wall can be given over to windows and doors without losing vital integrity. To help replace the strength lost, there will be either brick arches or beams made of stone or some other material placed on top of the window or door opening. Also those windows and doors that these buildings do have must be aligned vertically as the weight of the building is being held up very largely by the amount of wall lying between these vertical rows of windows.

Another feature of brick construction (and a very important one in consideration of the amount of cover provided by the walls) is that thicknesses of exterior walls are greatest for the ground floor and are made thinner for upper floors where there is less load to bear. In a common situation, the wall of a six-story brick building is twice as thick at ground floor level as it is at the sixth floor level (see Figure A-2).

Brick has been a very commonly used building material in cities throughout the world and accounts for a high proportion of the total, especially in the older parts of cities. Brick is used for buildings meant for a wide variety of uses although the most common use is for residential buildings, houses, and apartments. Brick is also very commonly used for stores, factories, offices, and public buildings. A note of caution, though, many buildings having brick exposed on the outer walls are actually framed structures covered with brick sheathing thin "curtain walls."

Block Buildings. Another common material is building block, the blocks being made of a wide variety of materials including concrete, pumice, and terra-cotta (clay). The principle that the wall bears the load of the building is the same as that for brick buildings although these materials are used for "in-filling," the making of nonload-bearing walls for steel and reinforced concrete framed buildings as well. Usually, block mass construction buildings are only one or two stories tall and thus there is no need for the ground floor wall to be thicker than the upper floor wall. When additional load-bearing strength is required, steel reinforcement bars are strung in holes in the blocks; mortar is then poured around the bars.

Block construction is often used for low-rise commercial buildings and factories. It also often forms the basic part of walls of houses; a layer of regular brick is usually employed as a sheathing.

Concrete Buildings. Concrete construction takes the three major forms 1) poured-in-place; 2) tilt-up; 3) box-wall principle.

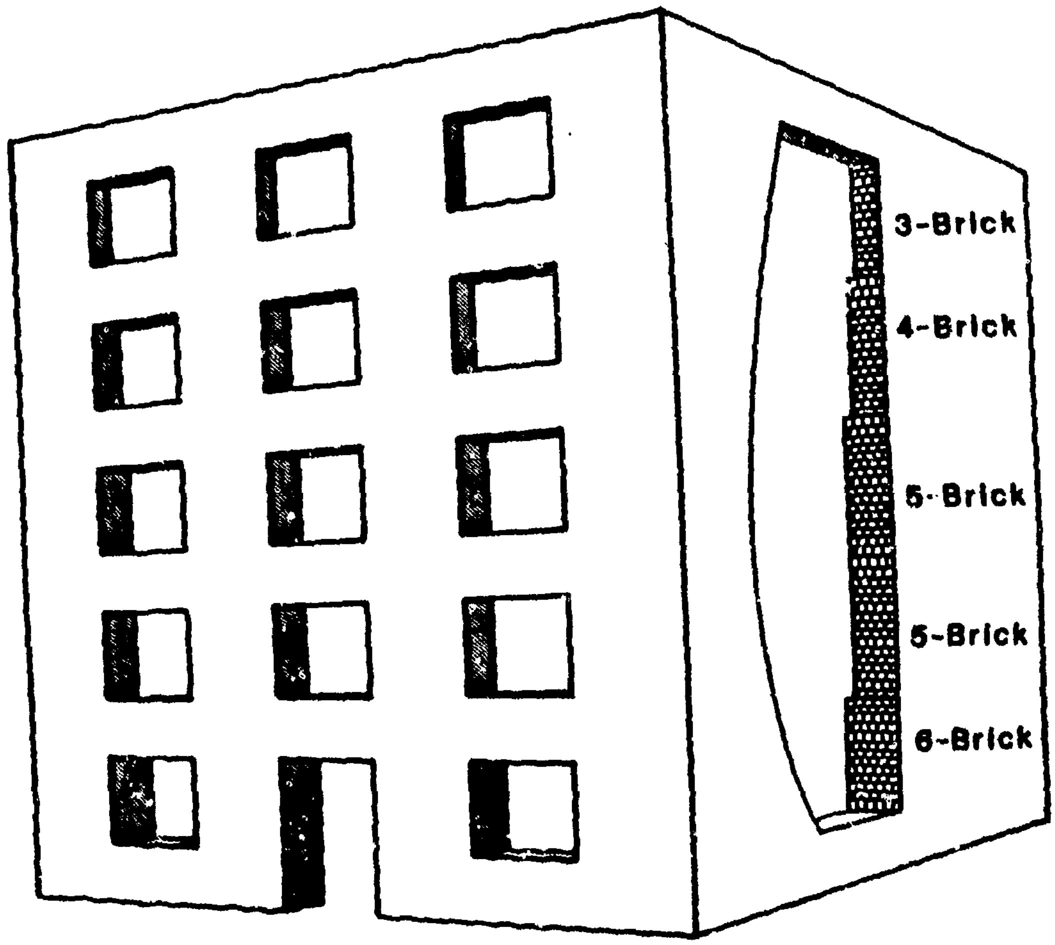


Figure A-2. Building types: I.D. characteristics (mass construction, brick).

Poured-in-Place Concrete Buildings. These are made by pouring concrete into forms to make walls and floors. Often, steel reinforcement is used to add strength. The walls have great load-bearing strength even though they are commonly only 15 to 20 centimeters thick. Also, because of their high density, they are quite resistent to lateral forces (as an incoming round). Often, even though such rounds make holes in the wall, the steel reinforcement bar remains intact. This method of construction is seen most in commercial buildings and in factories.

Tilt-Up Construction Buildings. Instead of pouring concrete into standing vertical forms (to make walls), concrete is poured into forms lying on the floor and then, when hardened, hoisted to an upright position to form a wall. A mesh steel wire reinforcement is commonly used to impart both tensile and compressive strength. The final product is a wall that is some 15 to 20 centimeters thick and is quite resistant to both vertical and horizontal forces. This form of construction is relatively new and is commonly seen in new low-rise industrial/storage zones in the United States. Considering the history of the spread of building technology, this form of construction can be expected to be seen in cities throughout the world sometime in the future.

Box-Wall Principle Buildings. This form of construction not only uses concrete for the walls but for floor/ceilings as well. These may either be poured-in-place or made elsewhere and transported to the construction site. In construction, a series of boxes or cells is formed, each of which supports the other. This method of construcion is well-suited for the building of which supports the other. The method of construction is well-suited for the building of apartments; each "cell" is often a single apartment.

Framed Construction

Framed construction has been widely used throughout the world for centuries. It is represented both in some very old forms and, since the introduction of modern building materials, some very new and important forms. Amongst the older are wooden post and lintel (beam) structures, seen widely in Europe where they are commonly known as "half-timbered" structures. Primitive forms, such as a bamboo-framed thatched hut, are common in rainy, tropical countries. But, frames are also modern for it was the arrival of steel and reinforced concrete frames that permitted erecting the "skyscrapers" associated with the modern city.

Wooden Post and Lintel

This method of construction used wooden posts and lintels (horizontal beams) to form a frame that bears the weight of the building and its contents. In the construction process, before any walls are put in place, these posts are set a few feet apart. (With balloon construction--the method used very widely in the U.S. to build detached wooden houses--the "skeleton" is very light, being composed of 2x4's set 16 inches apart).

Exterior walls are made by either placing material ("in-fill") in between the frame members, in the case of half-timbered buildings, or by adding a sheathing over the columns ("stud") in balloon construction. In either case, this material adds no load-bearing strength and is used only for protection from the weather, to provide stiffening to the frame, and to close off interior space.

Half-Timbered Buildings. These buildings have frames made of squared wooden timbers, usually about 8 inches thick (see Figures A-3). In most cases, the frames are exposed to view from the outside. Further strength is given by short, diagonal braces seen especially at the corners of buildings but also elsewhere in the structure.

The walls are made of various materials placed in between the frame members and are the same thickness as those columns, beams, and braces. Materials used at the time of construction were a single row of bricks or often just straw and mud. Repairs are often made today using any handy material, for example, brick, building block, etc. In all cases, though, the wall is far lighter than those of mass construction buildings. Holes can be punched in the walls using hand tools. Roofs are also fairly light, being made simply of rafters and stringers covered by terra-cotta tile.

Many times, especially in Germany, the walls of these old buildings (many are several hundred years old) have been covered with a sheathing of shingles, tar paper, plaster, or some other low-cost material to protect decaying walls from the elements. When these buildings are so covered, they may look, at a glance, much like brick structures whose outer walls have been sheathed by some other material. A major difference occurs, though, in the pattern of the windows. In mass construction buildings, windows are always aligned vertically. In half-timbered buildings--as with any framed buildings--windows can be placed anywhere along a wall (as long as they are between supporting columns of the frame) without reducing the strength of the structure.

Half-timbered buildings, built in great numbers over a period of several hundred years, are very common in many place in northwestern Europe. They are in current use for houses, barns, and stores. In many parts of Germany, they form the most common type of building in agricultural villages. In these instances, houses and barns are either very close to one another or are connected. Half-timbered buildings are also found in great numbers in central areas of small- to medium-sized towns. In larger cities, these small, old structures have been replaced by modern buildings in core areas and are found only in outlying parts of the city where agricultural villages have been surrounded by modern suburbs.

Balloon Construction Buildings. The practice of using small dimension "columns" and "beams" (2 x 4 inches or equivalent measurements) came about only with the widespread introuction of sawmills using power rip saws. These provided the means to reduce building construction costs and to simplify the process.

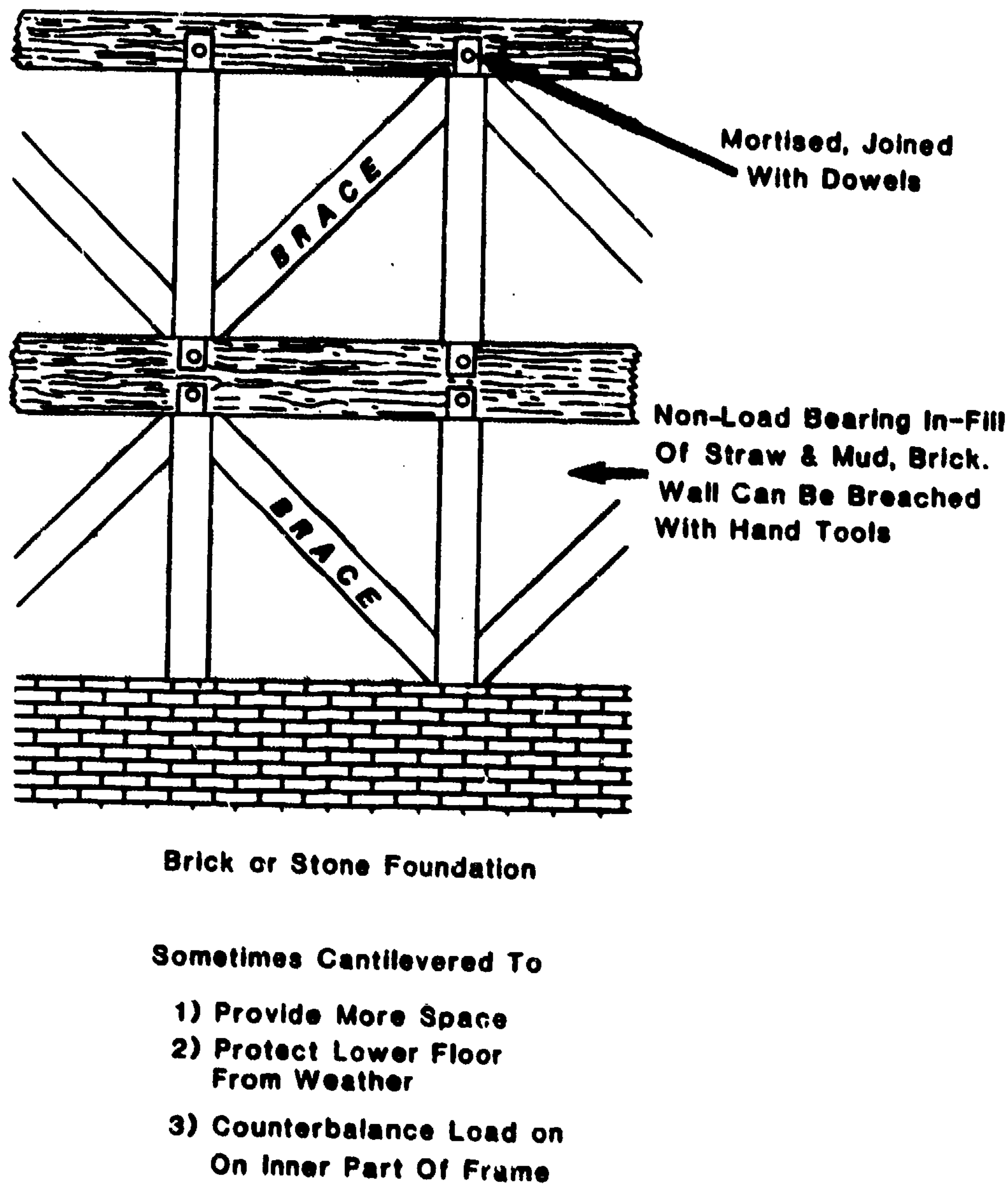


Figure A-3. Principles: Framed construction (general: wood post and beam principles).

The outer walls are formed by covering the frame with some form of "sheathing." Common materials are wood siding and a single width of brick. (Note: Many buildings that appear to be made of brick have only a sheathing of brick over a wooden frame. The sheathing is generally thin, no more than 10 centimeters. Such walls provide little cover.)

Roofs and floor/ceilings are very lightweight. Roofs also are light, consisting of rafters, stringers, and a covering of tar paper, tile, shingles, or shakes.

In these areas, balloon construction is used widely for many types of buildings. Housing, especially detached (both single family and small apartments) is the most common. Commercial businesses, small warehouses and factories, also use this form.

Steel or Reinforced Concrete Framed

Framed buildings, constructed since their invention in about 1890, have skeleton frames made of either steel girders (large 1-shaped members) or concrete poured in the shape of columns and beams around steel reinforcement bars. Whether these frames are made of one material or the other may be important where the collapse of a building is involved. Of immediate importance, though, is that with both types of frames, the exterior walls--being nonload-bearing--are thinner than those of mass construction buildings. Accordingly, they provide only slight amounts of cover.

The basic subdivision into heavy- and light-cladding refers to the thickness of the "curtain call" material (sheathing) that is placed over the frame. Heavy-clad buildings have composite curtain walls made of such items as ordinary brick, terra-cotta brick, and possibly a veneer of stone and are in the vicinity of 35 cm thick. Light-clad structures employ a variety of materials. Many around the world employ a single row of terra-cotta brick as "in-fill" material covered with a layer of plaster (see Figure 56, page 121). Others use glass, aluminum, decorative brick, and lightweight concrete aggregate.

Heavy-Cladding. The use of heavy-cladding was common for framed buildings constructed during the period from about 1890 to 1941 (Figure A-4). During that time, buildings were styled to look like traditional mass construction buildings. Light-cladding became popular after World War II and has been used almost exclusively for the large number of modern buildings that have been erected in cities since that time.

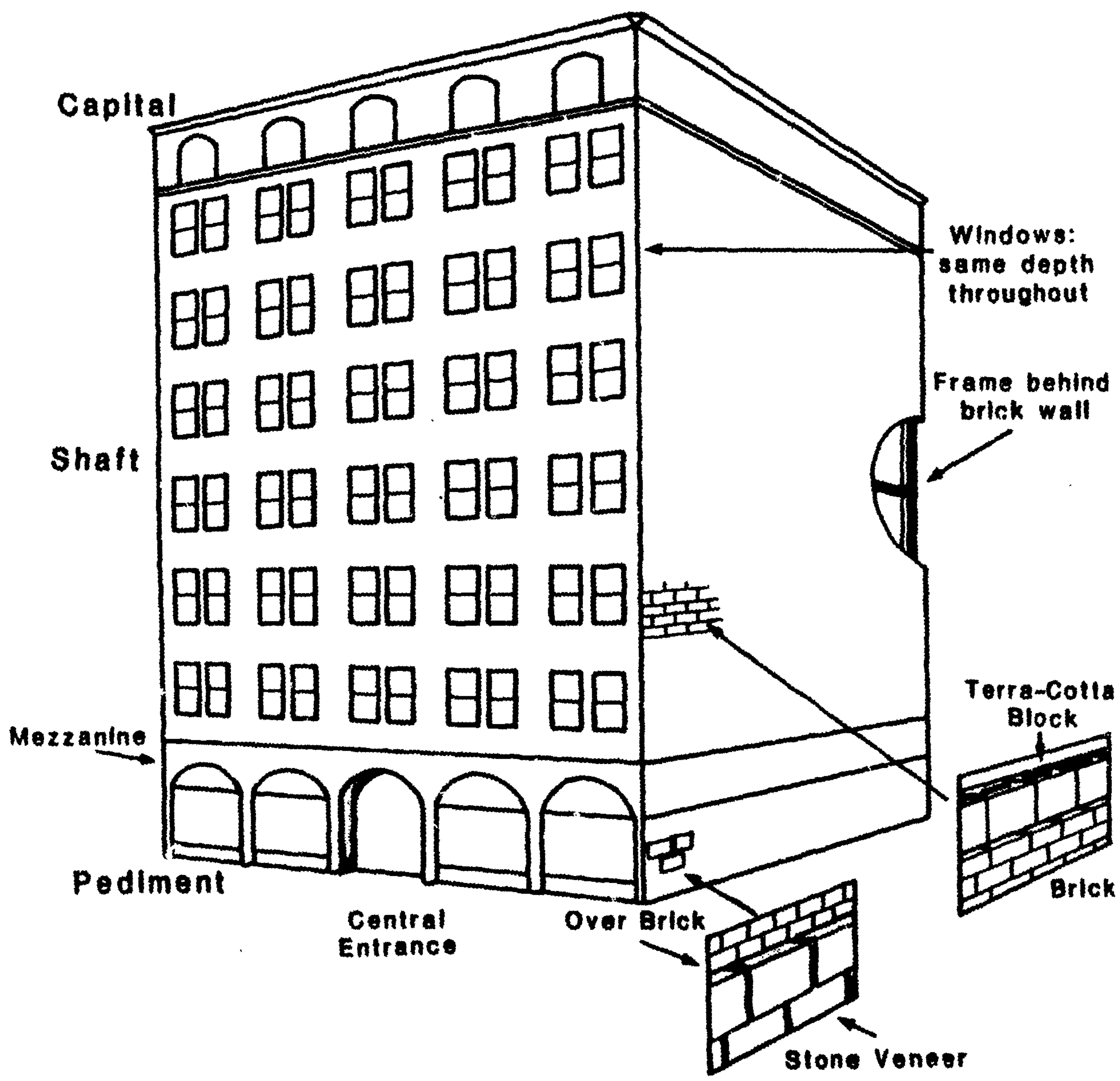


Figure A-4. Building types: I.D. characteristics (framed, heavy-clad).

Light-Cladding. These buildings (Figure A-5) are easily recognized by the obviously thin outer wall material, although sometimes buildings are designed to look "heavy" by prescribing use of lightweight concrete aggregate wall material (about 10 to 15 cm thick). Some have the entire exterior covered with glass. In most, glass forms a high percentage of the exterior wall. Others use a thick layer of aluminum, plastic, or some other composition material. None of these materials provide very much cover, except against small arms. Other parts of these buildings are lightweight as well. Floor/ceilings are sometimes made only of corrugated steel plus a floor and ceiling covering. Some have lightweight concrete floors. Others have floors laid over reinforced concrete floor joints of "waffle-pattern" concrete forms.

These buildings are especially common in downtown areas where they are used mostly for offices, hotels, and stores. They are also the most common building type in the "outer city" urban terrain zones. Another common use is the high-rise apartment buildings. These exist in virtually every country of the world and are especially prevalent in newly developed sections of cities in Africa, Asia, and Latin America. A variation of this construction method is also used widely for factory buildings. Common with factories (and warehouses) is the use of a light steel frame covered with light corrugated steel or some composition material.

Because of their often great height, these structures could be used for observation posts, keeping in mind that cover provided is slight. A possible use of offices in light-clad structures--which usually have large "open bay" rooms--would be deployment of "back-blast" weapons. A special variation of these light-clad buildings, the modern parking garage, has extra heavy floor/ceilings (to allow for the weight of vehicles). These could provide considerable cover against vertically falling munitions.

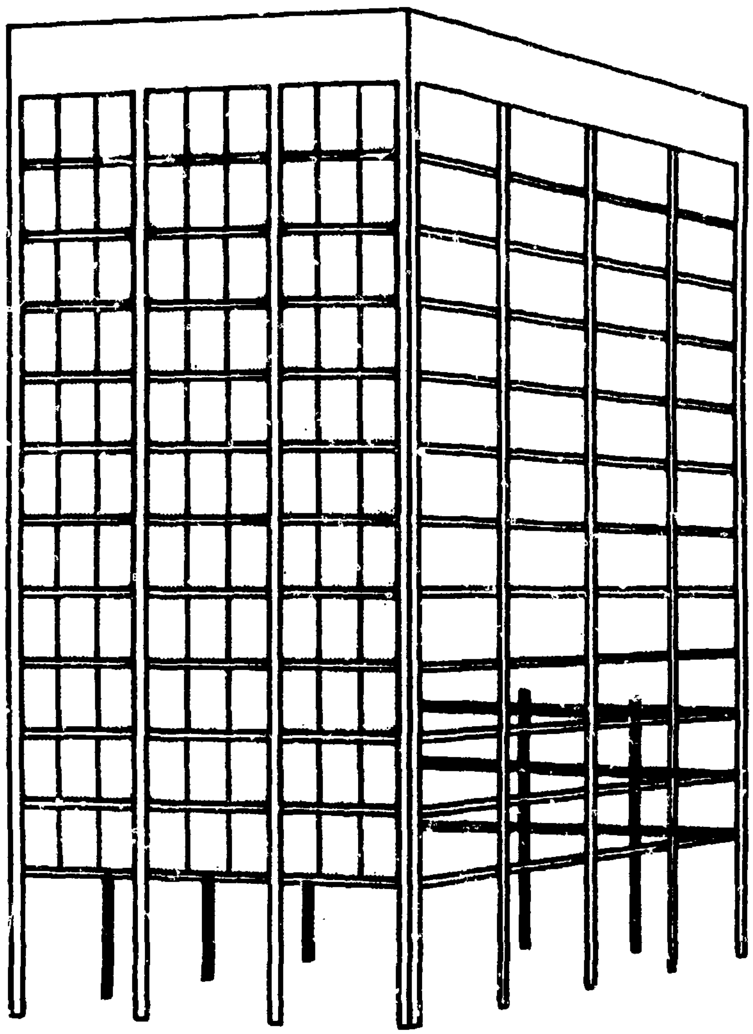


Figure A-5. Building types: I.D. characteristics (framed, light-clad).

APPENDIX B

BUILDING HEIGHT: TERRAIN ZONES

Table B-1

Building Height: Terrain Zones - Helsinki

	Number of Stories					
	1 to 5		5 to 15		15 to 30	
Terrain Zone	Percent	Dominant Height	Percent	Dominant Height	Percent	Dominant Height
A2	71	5	29	7		
A3	91	4	9	8		
A4	86	4	14	8		
A5	-	-				
A9	-	-				
Dc1	-	-				
Dc2	92	5	8	8		
Dc3	-	-				
Dc4	94	2	6	6		
Dc5	-	-				
Dc7	-	-				
Dc8	-	-				
Do1	100	1				
Do2	54	5	46	9		
Do3	100	2				
Do4	100	2				
Do5	100	2				
Do6	100	4				
Do31	-	-				

Table B-2

Building Height: Terrain Zones - Braunschweig

	Number of stories					
	1 to 5		5 to 15		15 to 30	
Terrain Zone	Percent	Dominant Height	Percent	Dominant Height	Percent	Dominant Height
A2	-	-				
A3	-	-				
A4	-	-				
A5	-	-				
A9	-	-				
Dc1			100	10		
Dc2	100	4				
Dc3	100	2				
Dc4	91	2	6	6		
Dc5	-	-				
Dc7	100	2				
Dc8	-	-				
Do1	100	1				
Do2	88	4	12	10		
Do3	100	2				
Do4	100	2				
Do5	-	-				
Do6	87	4	13	7		
Do31	100	1				

Table B-3

Building Height: Terrain Zones - Stuttgart

	Number of stories					
	1 to 5		5 to 15		15 to 30	
Terrain Zone	Percent	Dominant Height	Percent	Dominant Height	Percent	Dominant Height
A2	100	5				
A3	100	4				
A4	100	4				
A5	100	3				
A9	-	-				
Dc1	-	-				
Dc2	100	4				
Dc3	100	2				
Dc4	84	2				
Dc5	-	-				
Dc7	100	3				
Dc8	-	-				
Do1	-	-				
Do2	83		17	8		
Do3	100	2				
Do4	100	2				
Do5	-	-				
Do6	87	3	13	6		
Do31	-	-				

Table B-4

Building Height: Terrain Zones - Vienna

Terrain Zone	Number of stories: 1 to 5		5 to 15		15 to 30	
	Percent	Dominant Height	Percent	Dominant Height	Percent	Dominant Height
A2	75	5	25	8		
A3	100	4				
A4	100	4				
A5	100	5				
A9	-	-				
Dc1	-	-				
Dc2	95	4	5	7		
Dc3	100	2				
Dc4	100	2				
Dc5	-	-				
Dc7	100	2				
Dc8	-	-				
Do1	-	-				
Do2	66	5	34	10		
Do3	100	2				
Do4	100	2				
Do5	-	-				
Do6	95	5	5	7		
Do31	100	1				

Table B-5

Building Height: Terrain Zones - Athens-Piraeus

	Number of stories					
	1 to 5		5 to 15		15 to 30	
Terrain Zone	Percent	Dominant Height	Percent	Dominant Height	Percent	Dominant Height
A2	25	5	75	9		
A3	100	4				
A4	100	3				
A5	-	-				
A9	-	-				
Dc1	-	-				
Dc2	88	5	12	7		
Dc3	100	3				
Dc4	91	2	9	7		
Dc5	-	-				
Dc7	-	-				
Dc8	-	-				
Do1	-	-				
Do2	36	5	64	12		
Do3	100	2				
Do4	100	2				
Do5	67	5	33	9		
Do6	81	4	19	8		
Do31	-	-				

Table B-6

Building Height: Terrain Zones - Tel Aviv-Yafo

	Number of stories					
	1 to 5		5 to 15		15 to 30	
Terrain Zone	Percent	Dominant Height	Percent	Dominant Height	Percent	Dominant Height
A2	56	4	44	7		
A3	100	3				
A4	100	3				
A5	-	-				
A9	-	-				
Dc1	-	-				
Dc2	80	4	20	10		
Dc3	100	2				
Dc4	100	2				
Dc5	-	-	100	12		
Dc7	100	1				
Dc8	-	-				
Do1	-	-				
Do2	9	5	91	10		
Do3	100	2				
Do4	100	2				
Do5	-	-				
Do6	92	4	8	6		
Do31	-	-				

Table B-7

Building Height: Terrain Zones - Beirut

	Number of stories					
	1 to 5		5 to 15		15 to 30	
Terrain Zone	Percent	Dominant Height	Percent	Dominant Height	Percent	Dominant Height
A2	10	5	51	10	39	22
A3	69	5	31	10		
A4	57	5	43	8		
A5	-	-				
A9	-	-				
Dc1	-	-			100	25
Dc2	38	5	37	12	25	20
Dc3	100	2				
Dc4	88	2	12	6		
Dc5	-	-				
Dc7	-	1				
Dc8	100	-				
Do1	-	-				
Do2	-	-	26	12	74	25
Do3	-	-				
Do4	100	2				
Do5	-	-				
Do6	81	4	19	10		
Do31	-	-				

Table B-8

Building Height: Terrain Zones - Colombo

	Number of stories					
	1 to 5		5 to 15		15 to 30	
Terrain Zone	Percent	Dominant Height	Percent	Dominant Height	Percent	Dominant Height
A2	-	-				
A3	100	2				
A4	86	2	14	6		
A5	100	4				
A9	-	-				
Dc1	-	-	100	10		
Dc2	100	3				
Dc3	100	2				
Dc4	92	2	8	6		
Dc5	-	-				
Dc7	-	-				
Dc8	100	1				
Do1	-	-				
Do2	95	4	5	10		
Do3	100	2				
Do4	100	1				
Do5	-	-				
Do6	87	3	13	7		
Do31	-	-				

Table B-9

Building Height: Terrain Zones - Kuala Lumpur

Terrain Zone	Number of stories: 1 to 5 — Percent	1 to 5 — Dominant Height	5 to 15 — Percent	5 to 15 — Dominant Height	15 to 30 — Percent	15 to 30 — Dominant Height
A2	100	4				
A3	100	3				
A4	100	3				
A5	100	4				
A9	-	-				
Dc1	-	-				
Dc2	77	5	23	7		
Dc3	100	2				
Dc4	100	2				
Dc5	-	-	33	12	67	30
Dc7	-	-				
Dc8	-	0				
Do1	-	-	100	5		
Do2	73	5	27	12		
Do3	100	2				
Do4	100	3				
Do5	100	2				
Do6	79	4	21	8		
Do31	-	-				

Table B-10

Building Height: Terrain Zones - San Jose

	Number of stories					
	1 to 5		5 to 15		15 to 30	
Terrain Zone	Percent	Dominant Height	Percent	Dominant Height	Percent	Dominant Height
A2	75	4	25	12		
A3	100	2				
A4	100	3				
A5	80	4	20	6		
A9	-	-				
Dc1	-	-	100	12		
Dc2	100	3				
Dc3	100	2				
Dc4	100	4				
Dc5	-	-				
Dc7	-	-				
Dc8	-	0				
Do1	100	1				
Do2	100	5				
Do3	100	2				
Do4	100	3				
Do5	-	-				
Do6	76	4	24	10		
Do31	-	-				

Table B-11

Building Height: Terrain Zones - Panama City

	Number of stories: 1 to 5		5 to 15		15 to 30	
Terrain Zone	Percent	Dominant Height	Percent	Dominant Height	Percent	Dominant Height
A2	-	-	-	-	-	-
A3	100	2				
A4	100	3				
A5	100	4				
A9	100	2				
Dc1	-	-	100	12		
Dc2	100	2				
Dc3	100	1				
Dc4	100	2				
Dc5			100	15		
Dc7	-	-				
Dc8	100	1				
Do1	100	2				
Do2	18	4	52	12	30	20
Do3	100	1				
Do4	100	2				
Do5	100	1				
Do6	63	4	37	7		
Do31	-	-				

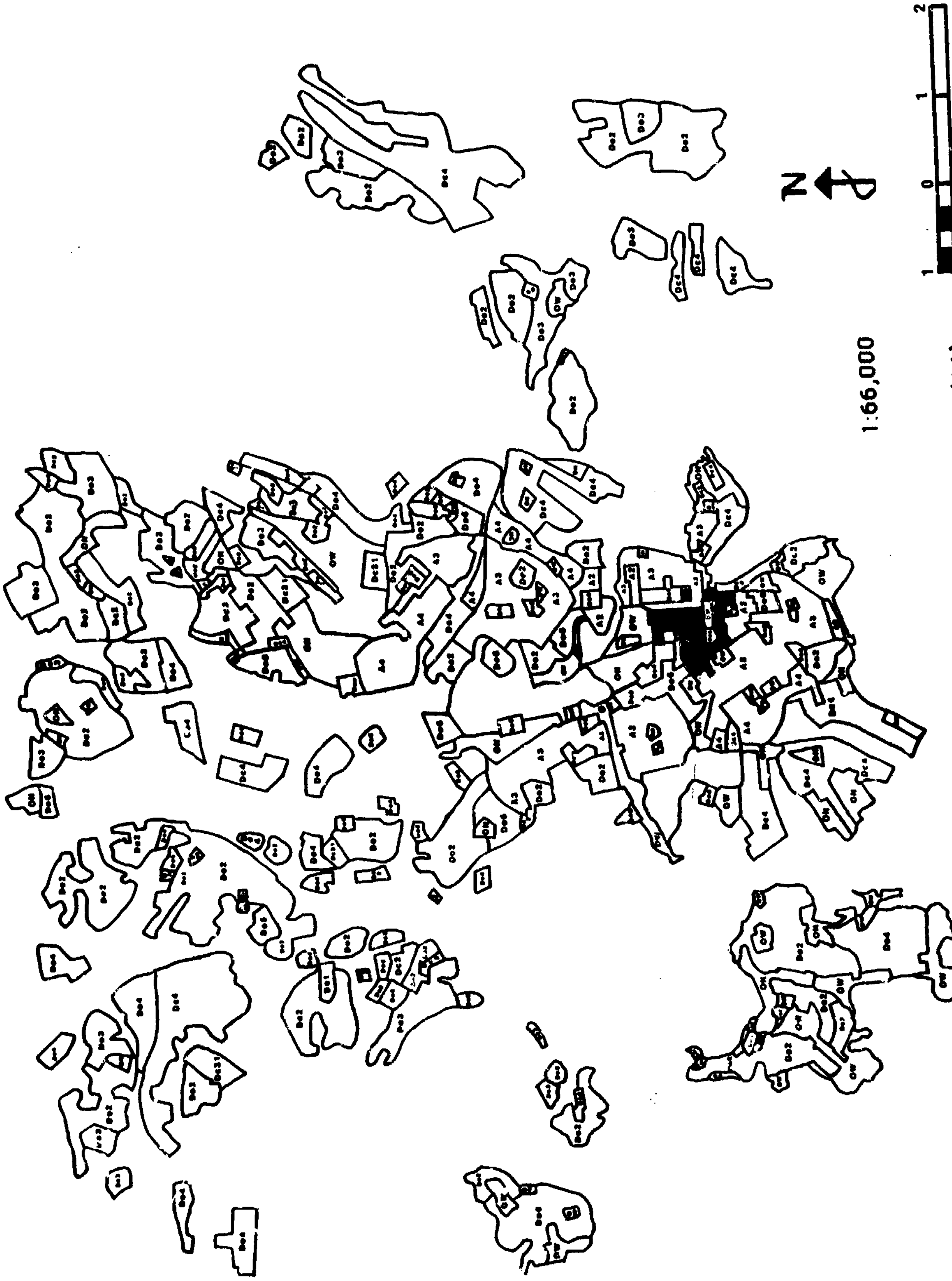
Table B-12

Building Height: Terrain Zones - Panama City

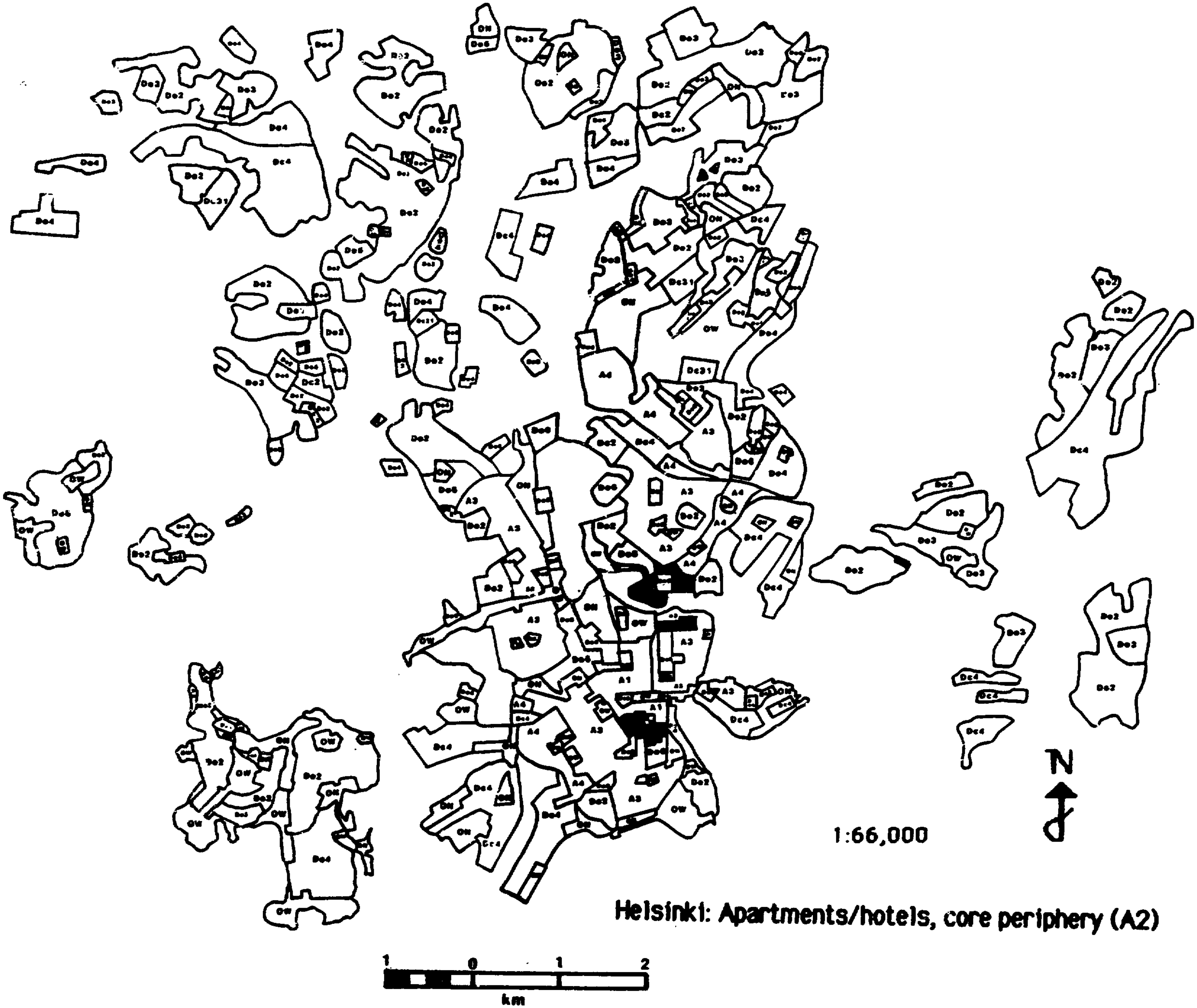
Terrain Zone	Number of stories: 1 to 5 — Percent	1 to 5 — Dominant Height	5 to 15 — Percent	5 to 15 — Dominant Height	15 to 30 — Percent	15 to 30 — Dominant Height
A2	37	4	49	12	14	20
A3	100	2				
A4	100	2				
A5	60	3	40	12		
A9	100	1				
Dc1	-	-				
Dc2	7	4	61	12	32	25
Dc3	100	2				
Dc4	94	2	6	7		
Dc5					100	30
Dc7	-	-				
Dc8	100	1				
Do1	-	-				
Do2			37	10	63	20
Do3	-	-				
Do4	100	2				
Do5	50	4	50	7		
Do6	63	4	37	10		
Do31	-	-				

APPENDIX C

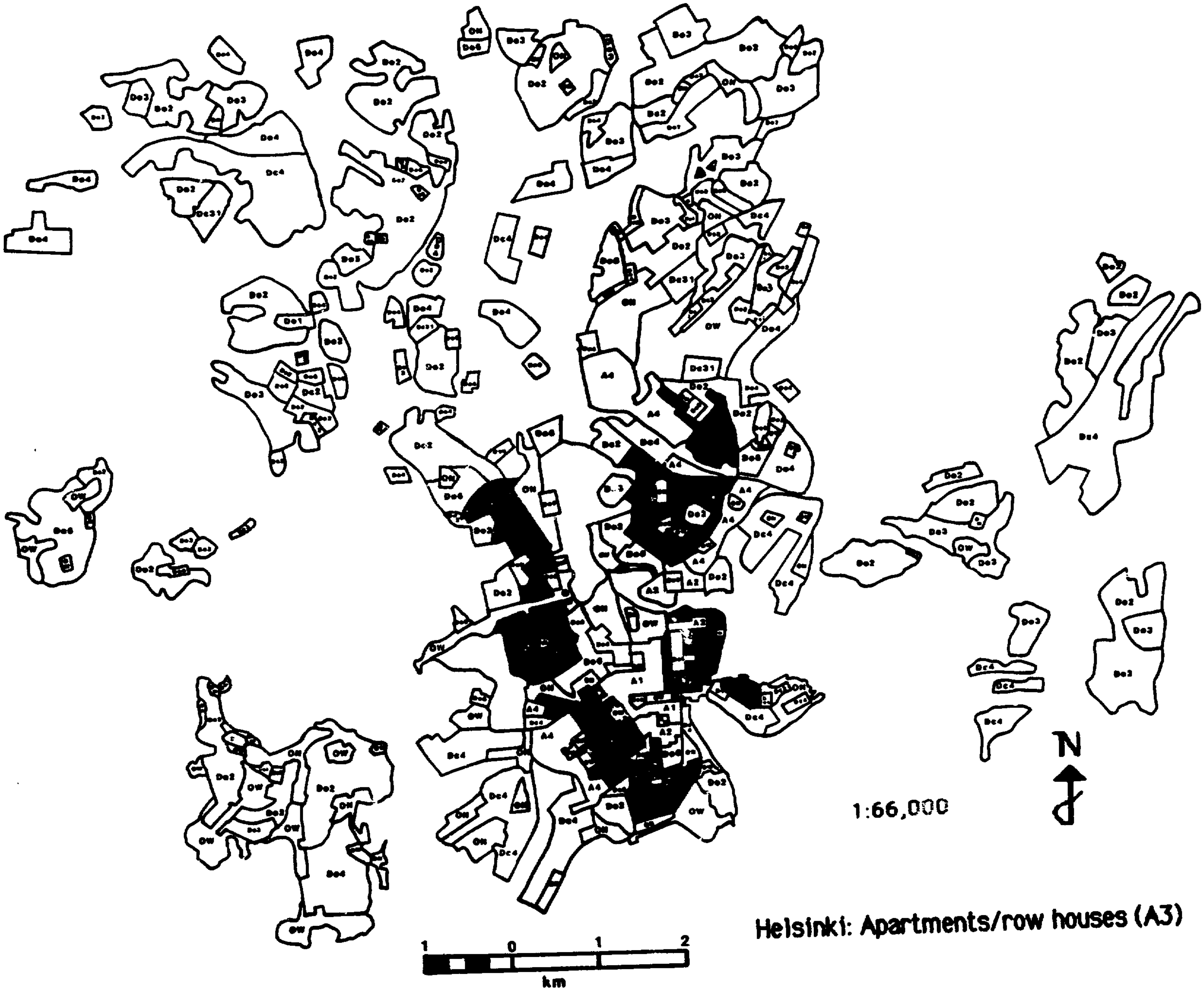
THEMATIC URBAN TERRAIN ZONE MAPS



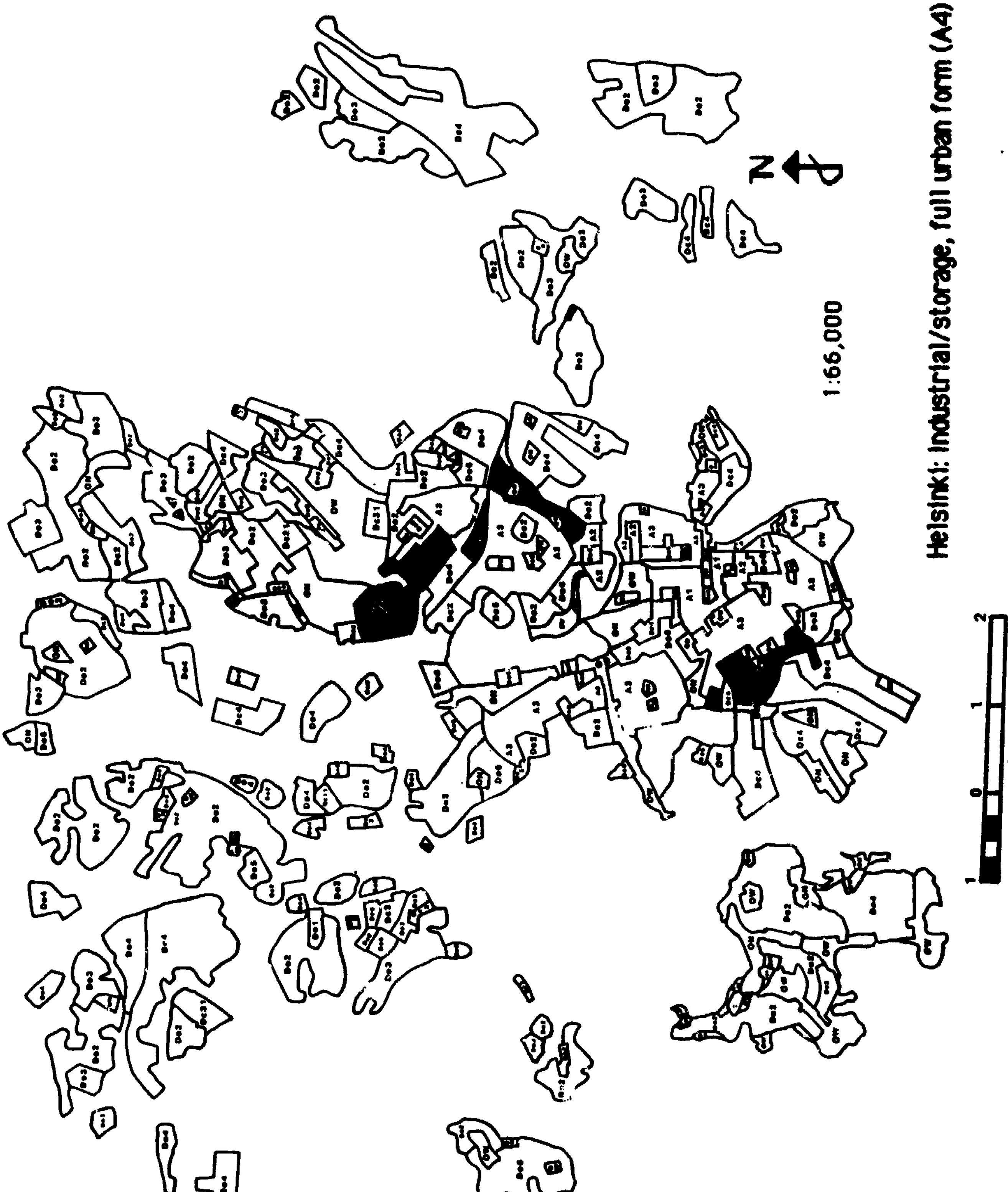
Helsinki: Core Area (A1)



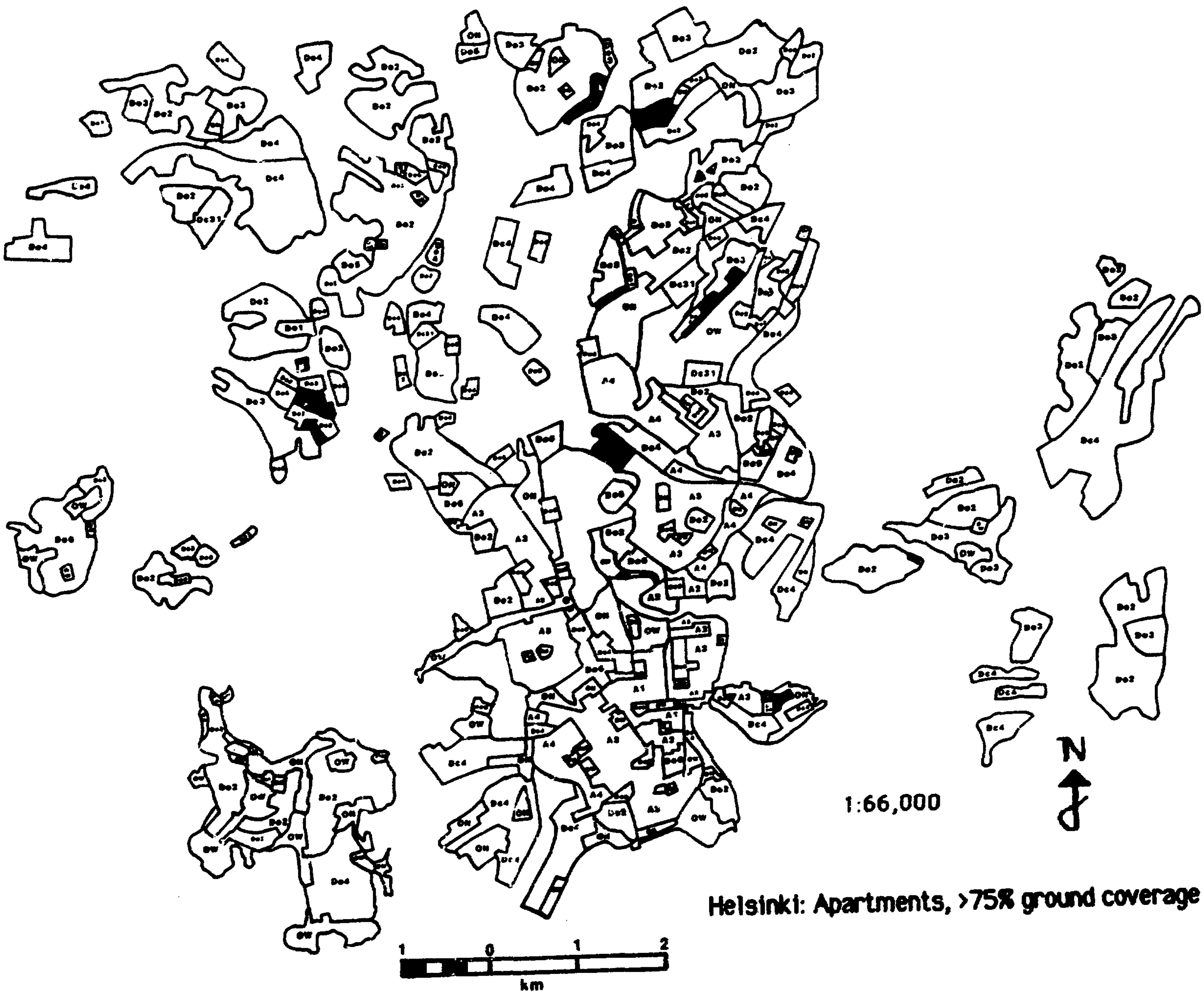
Helsinki: Apartments/hotels, core periphery (A2)



Helsinki: Apartments/row houses (A3)

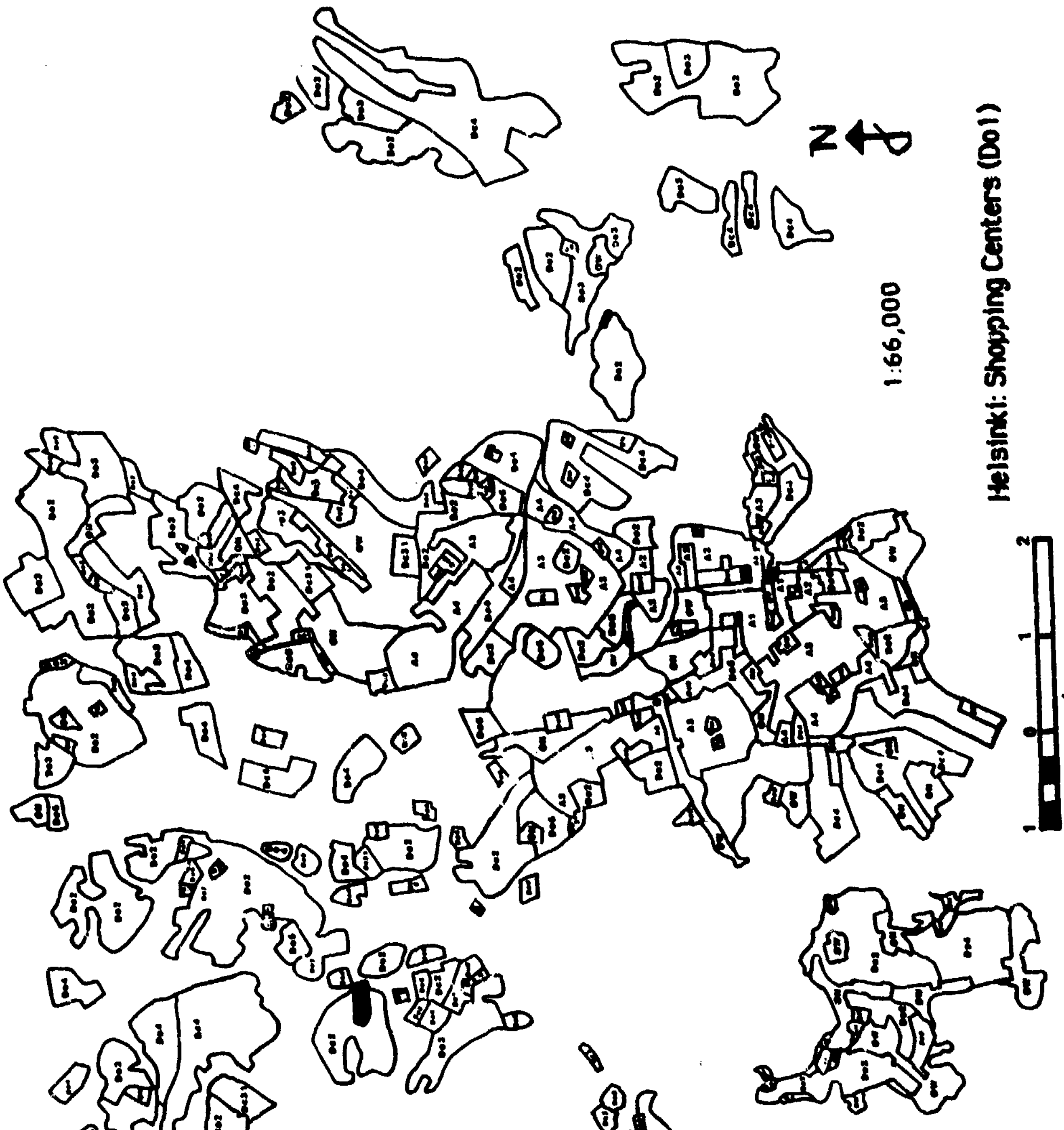


Helsinki: Industrial/storage, full urban form (A4)

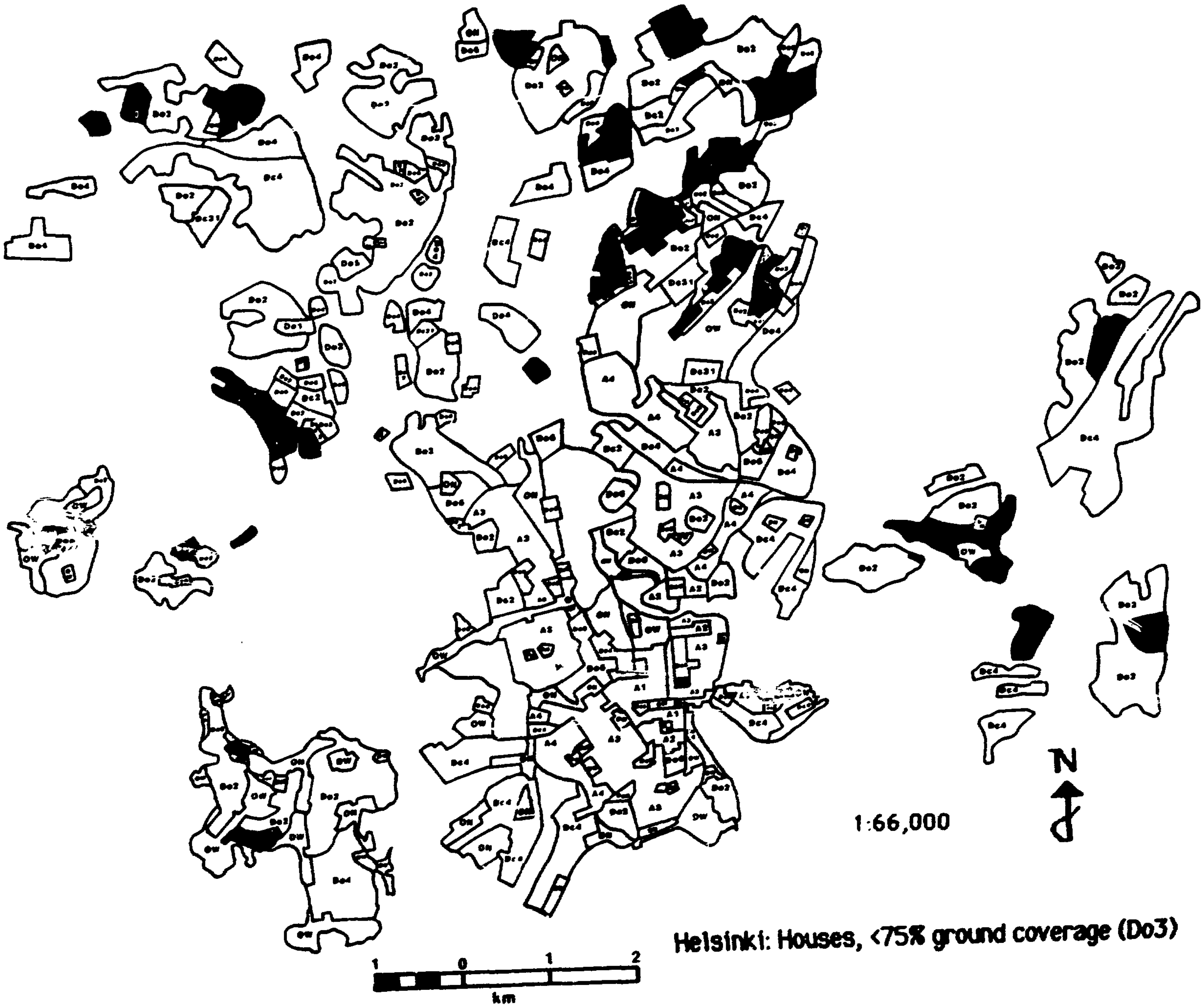


Helsinki: Apartments, >75% ground coverage (Dc2)

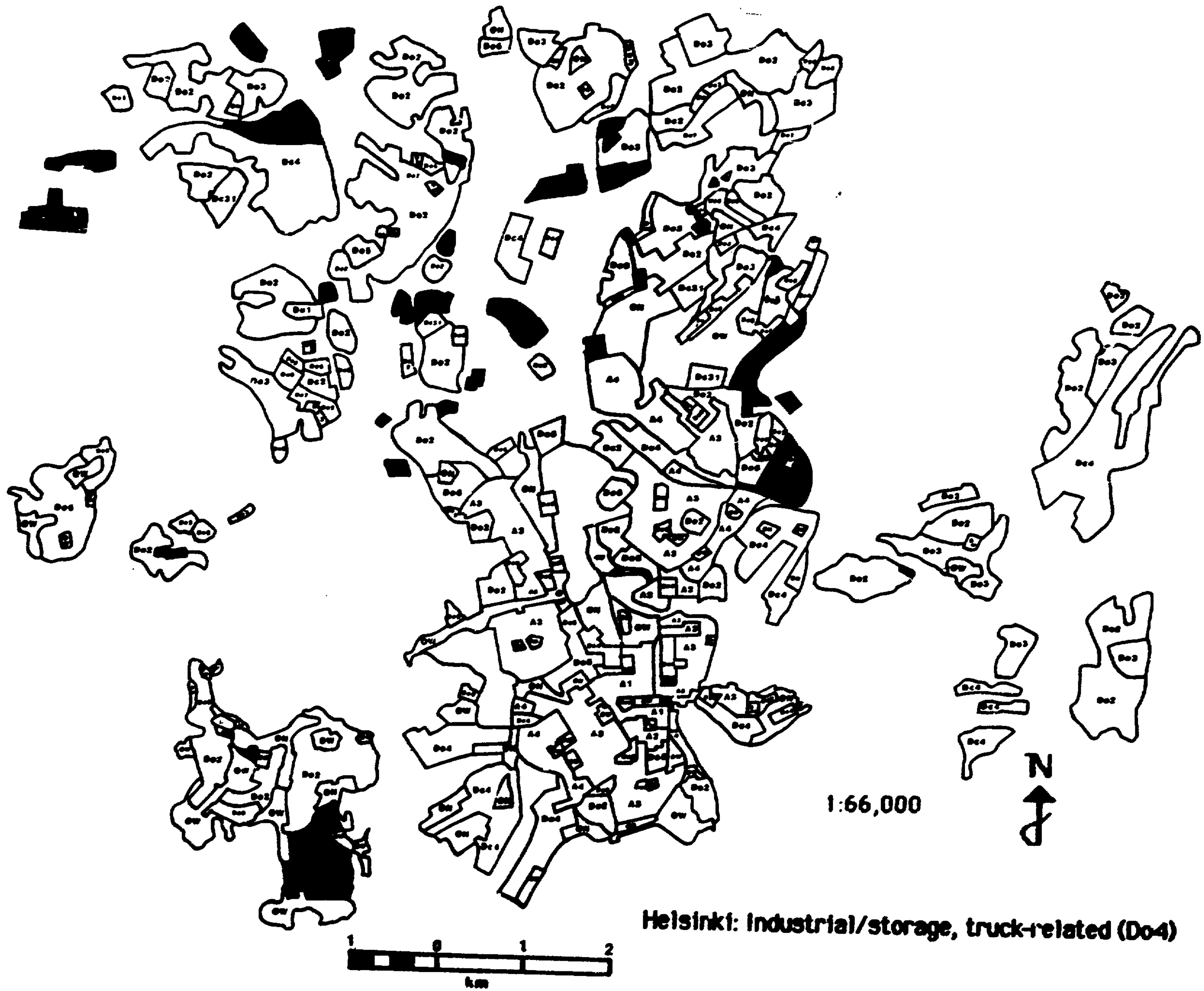
Helsinki: Industrial/storage, RR or dock-related (Dc4)


Helsinki: Shopping Centers (Do1)
1:66,000
N
1 0 1 2
km

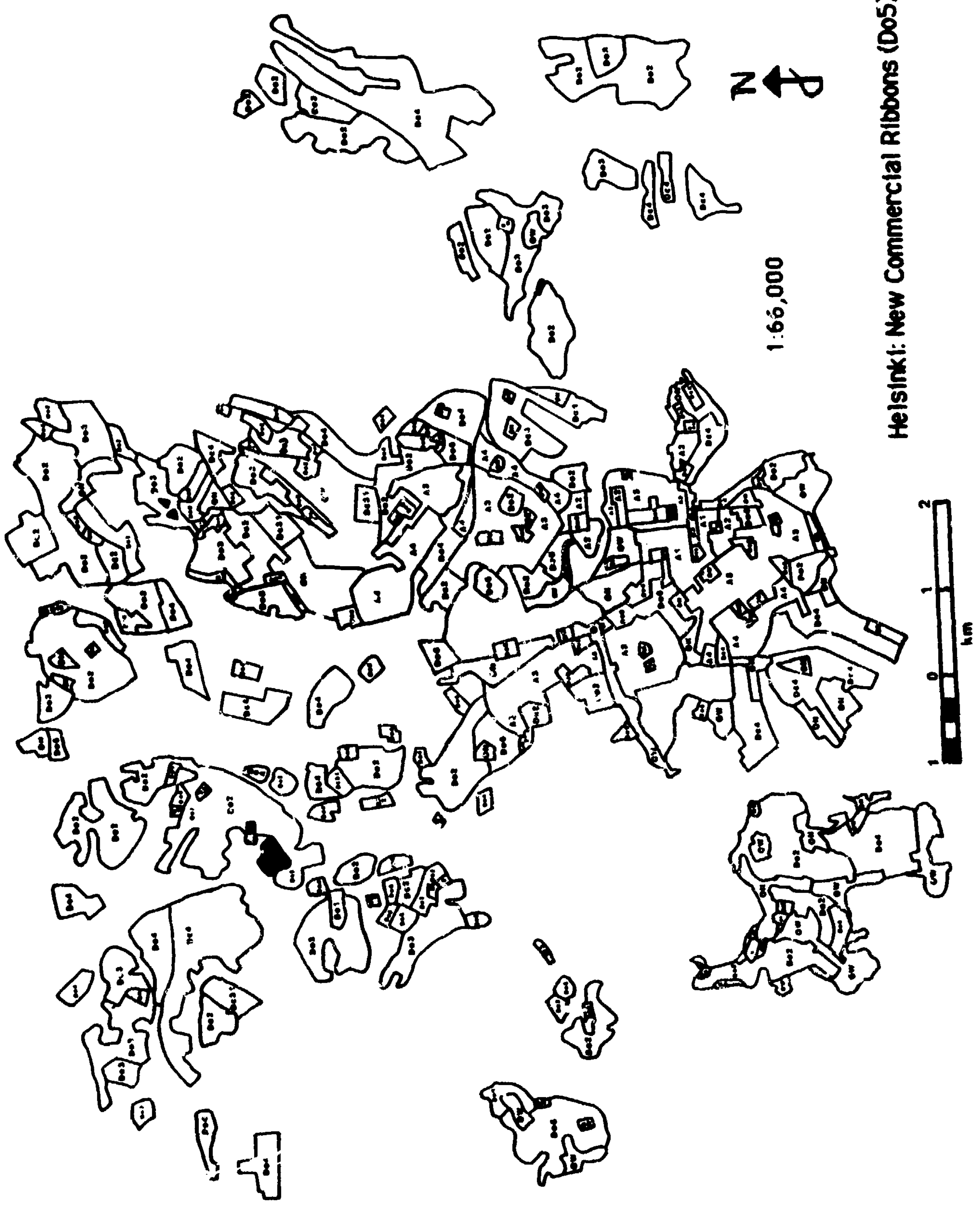
Helsinki: Apartments, <75% ground coverage (Do2)



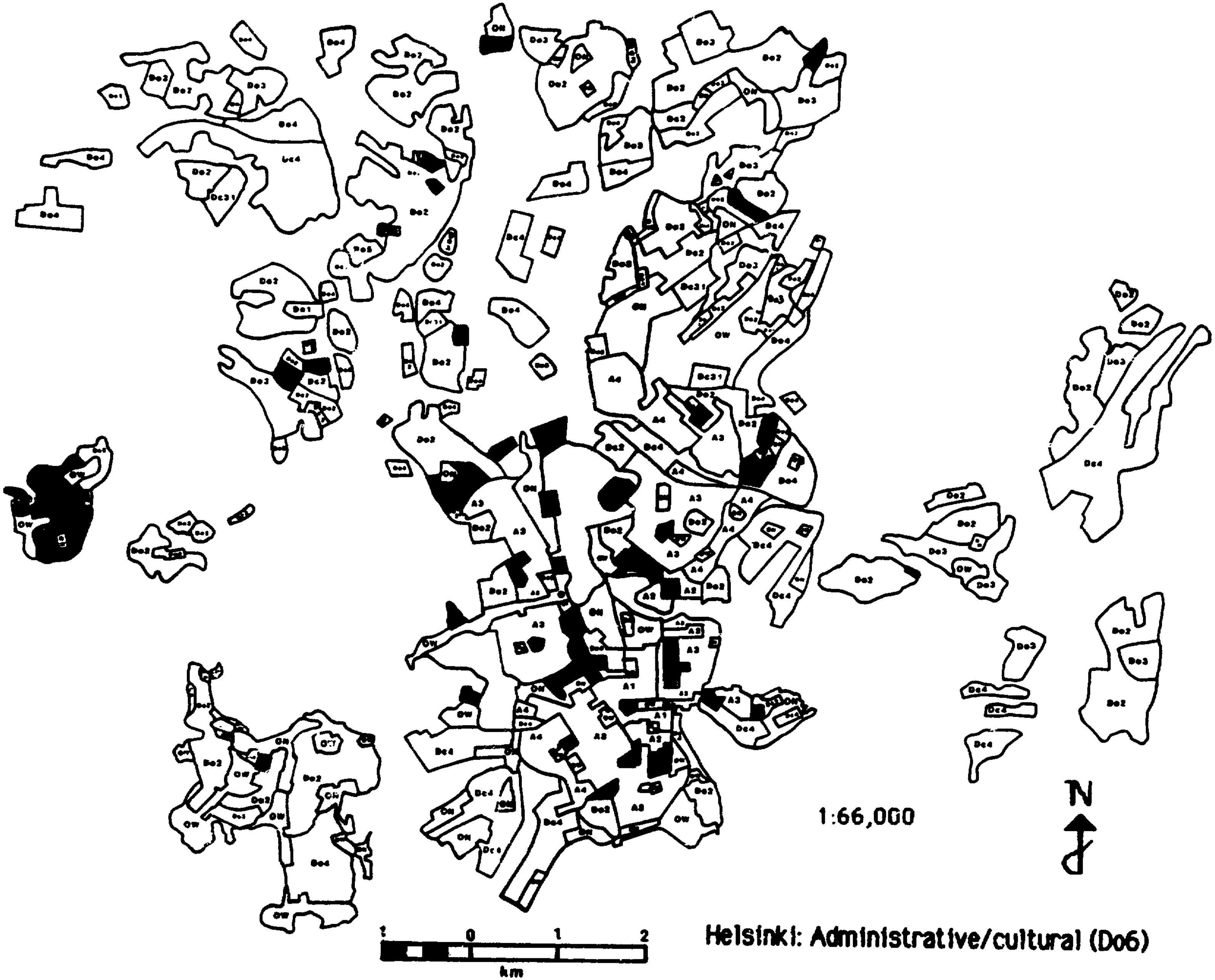
Helsinki: Houses, <75% ground coverage (Do3)



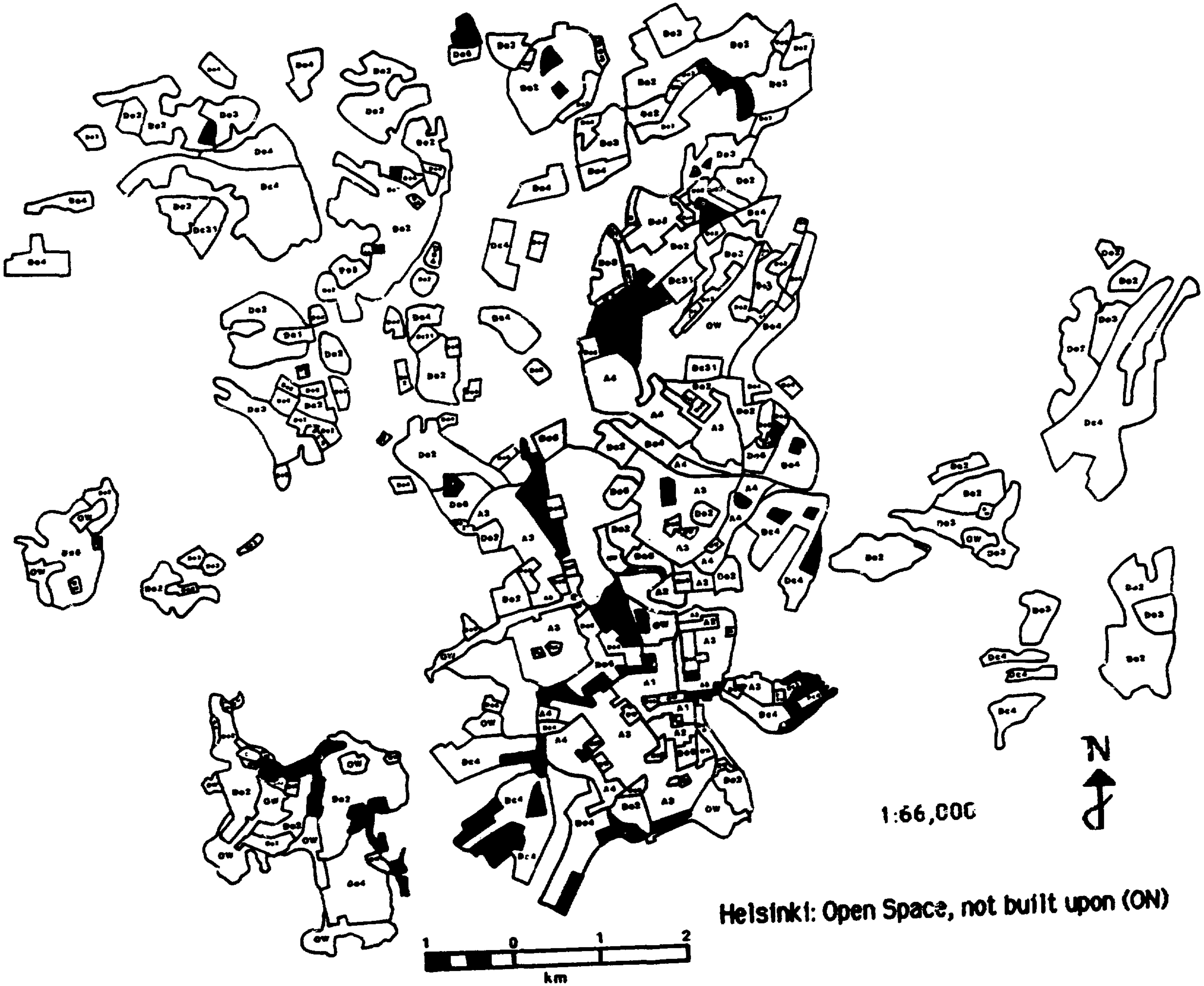
Helsinki: Industrial/storage, truck-related (Do4)



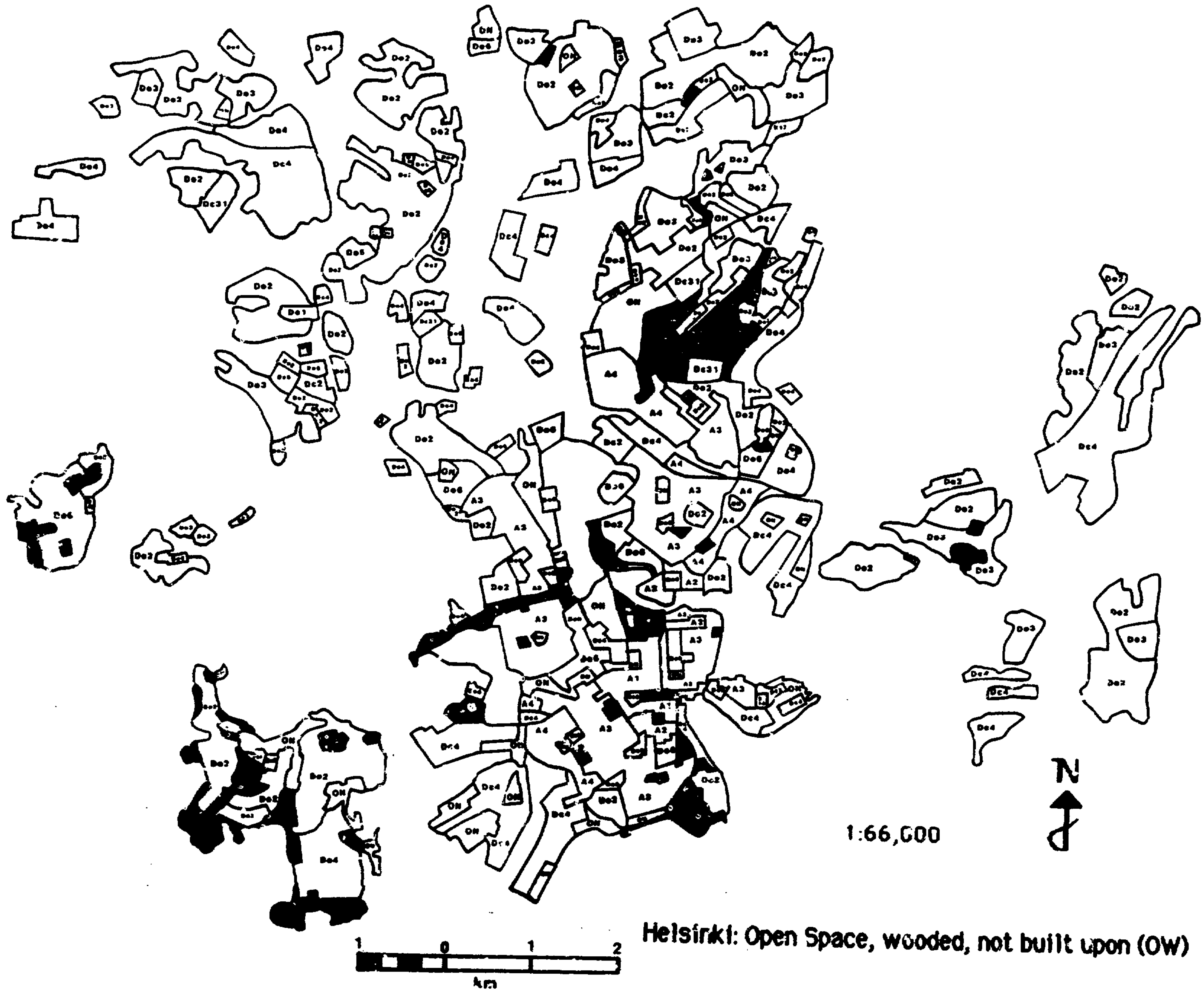
Helsinki: New Commercial Ribbons (Do5)



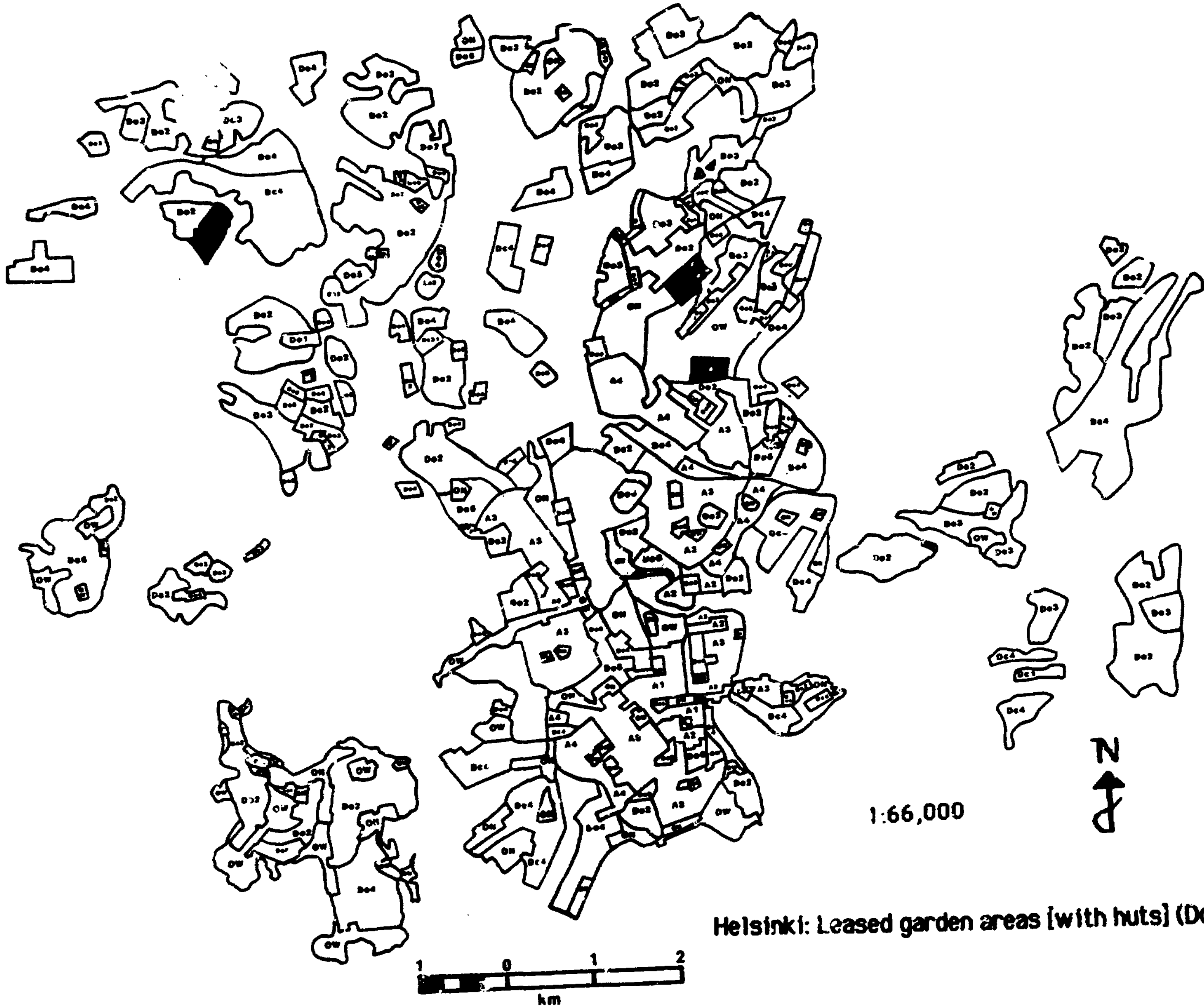
Helsinki: Administrative/cultural (Do6)



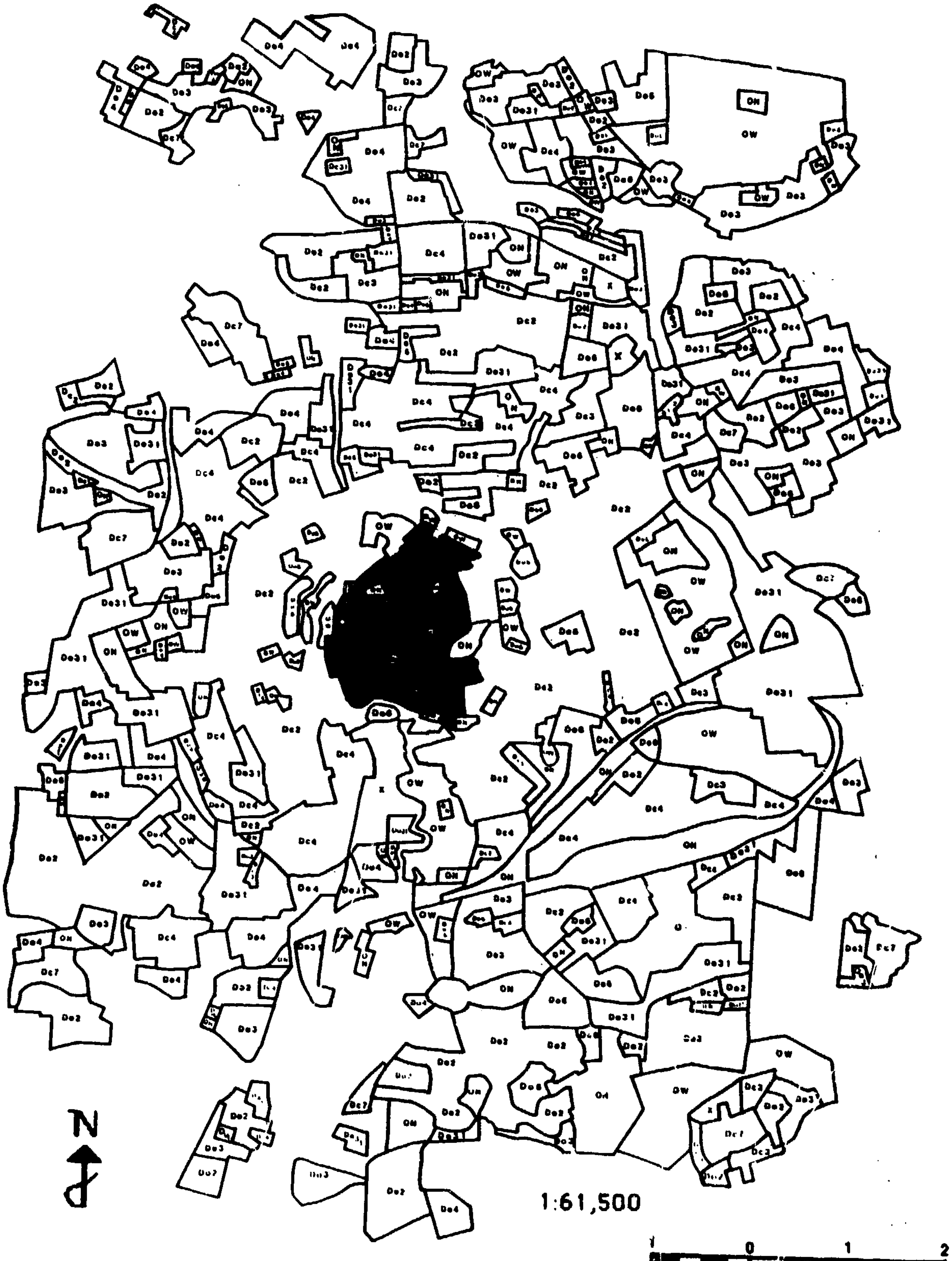
Helsinki: Open Space, not built upon (ON)



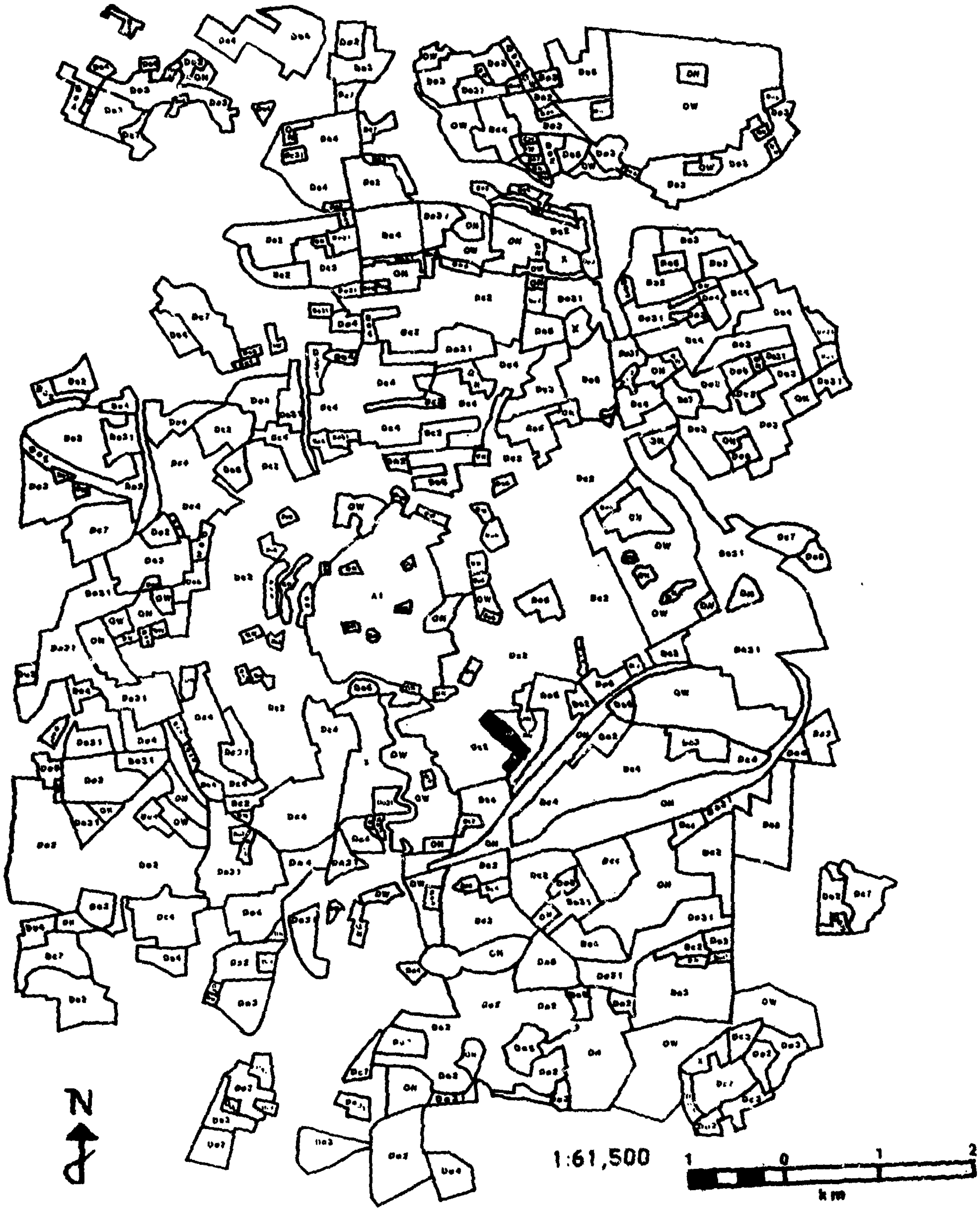
Helsinki: Open Space, wooded, not built upon (OW)



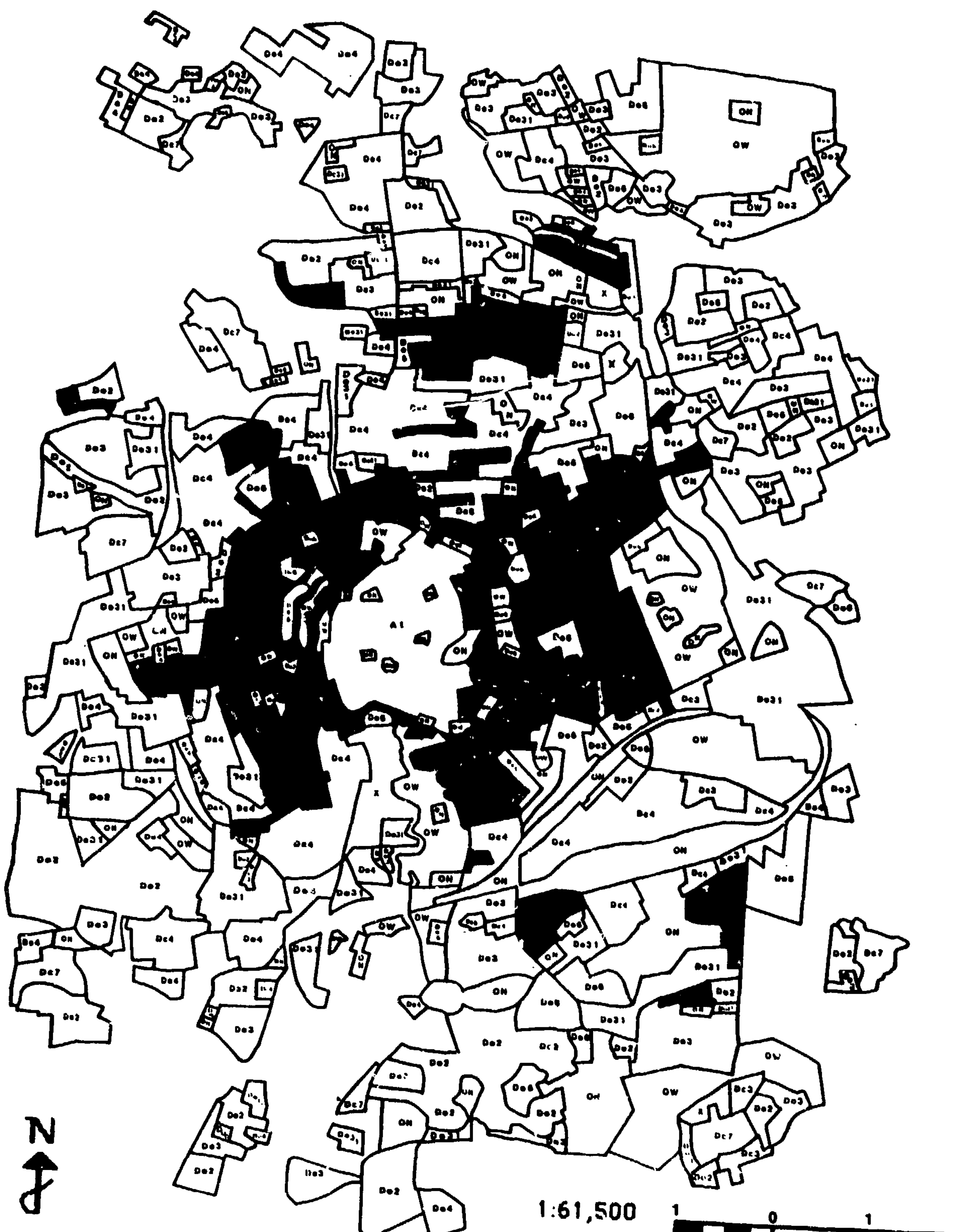
Helsinki: Leased garden areas [with huts] (Do31)



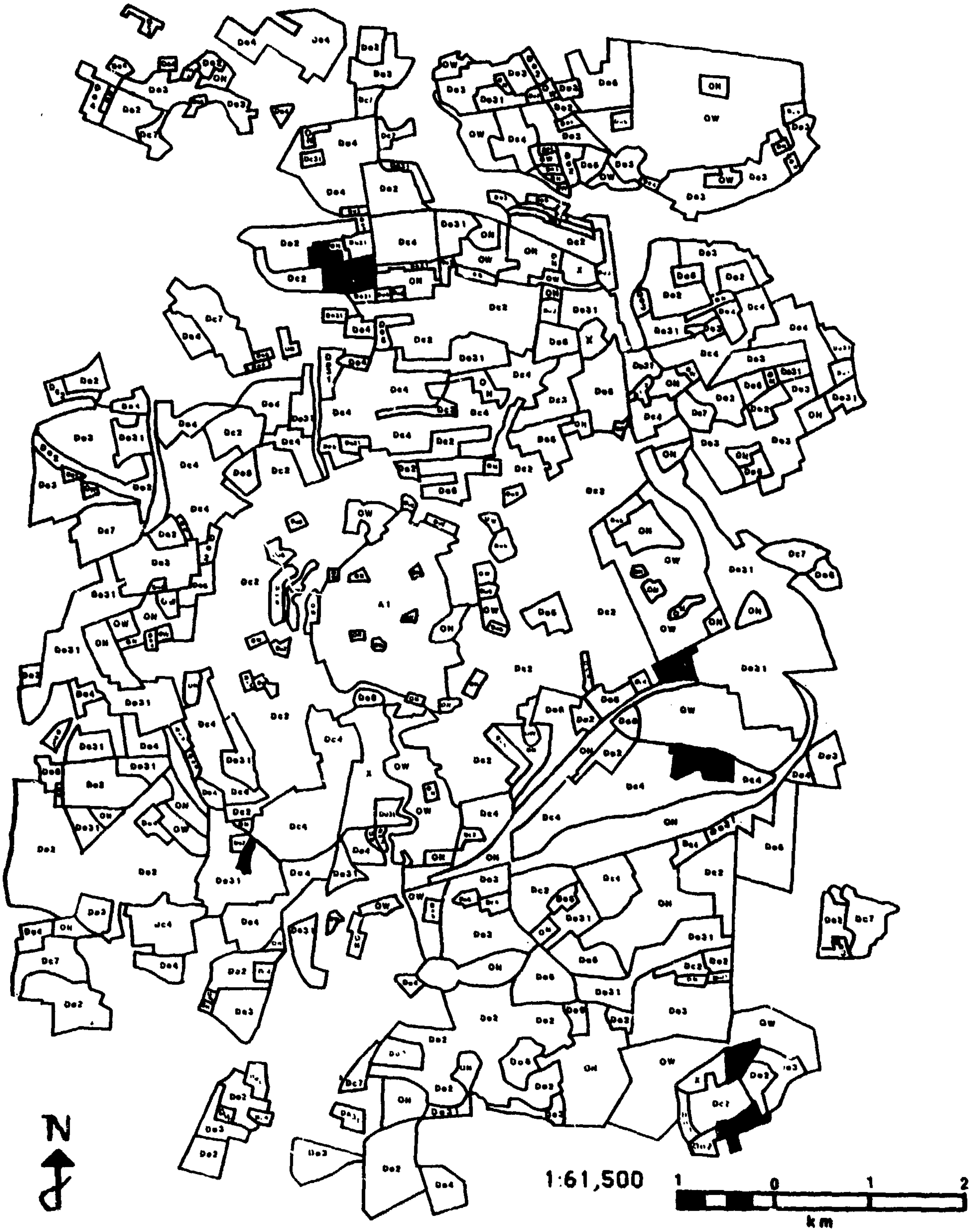
Braunschweig: Core Area (A1)



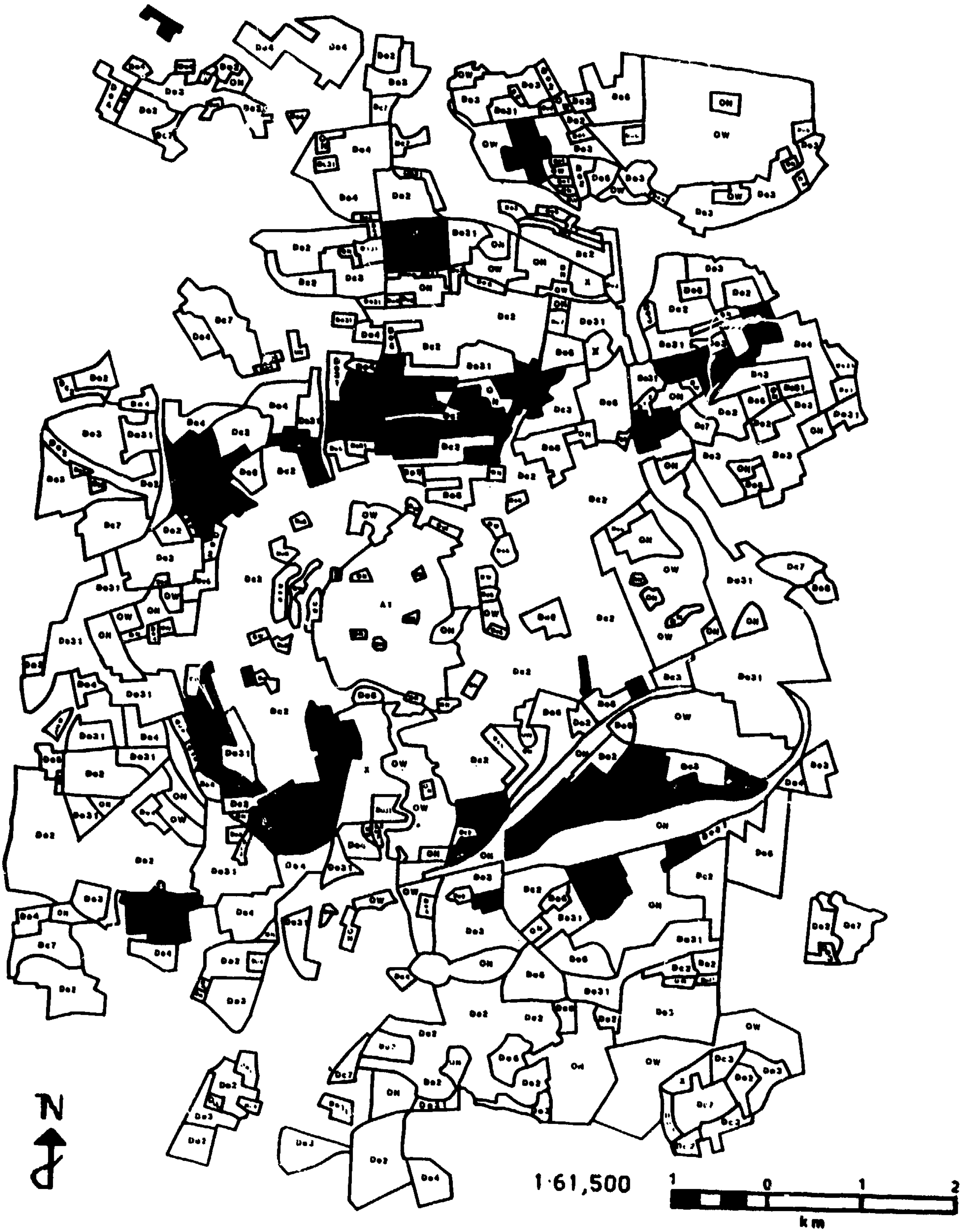
Braunschweig: Urban Redeveloped core area (Dc1)



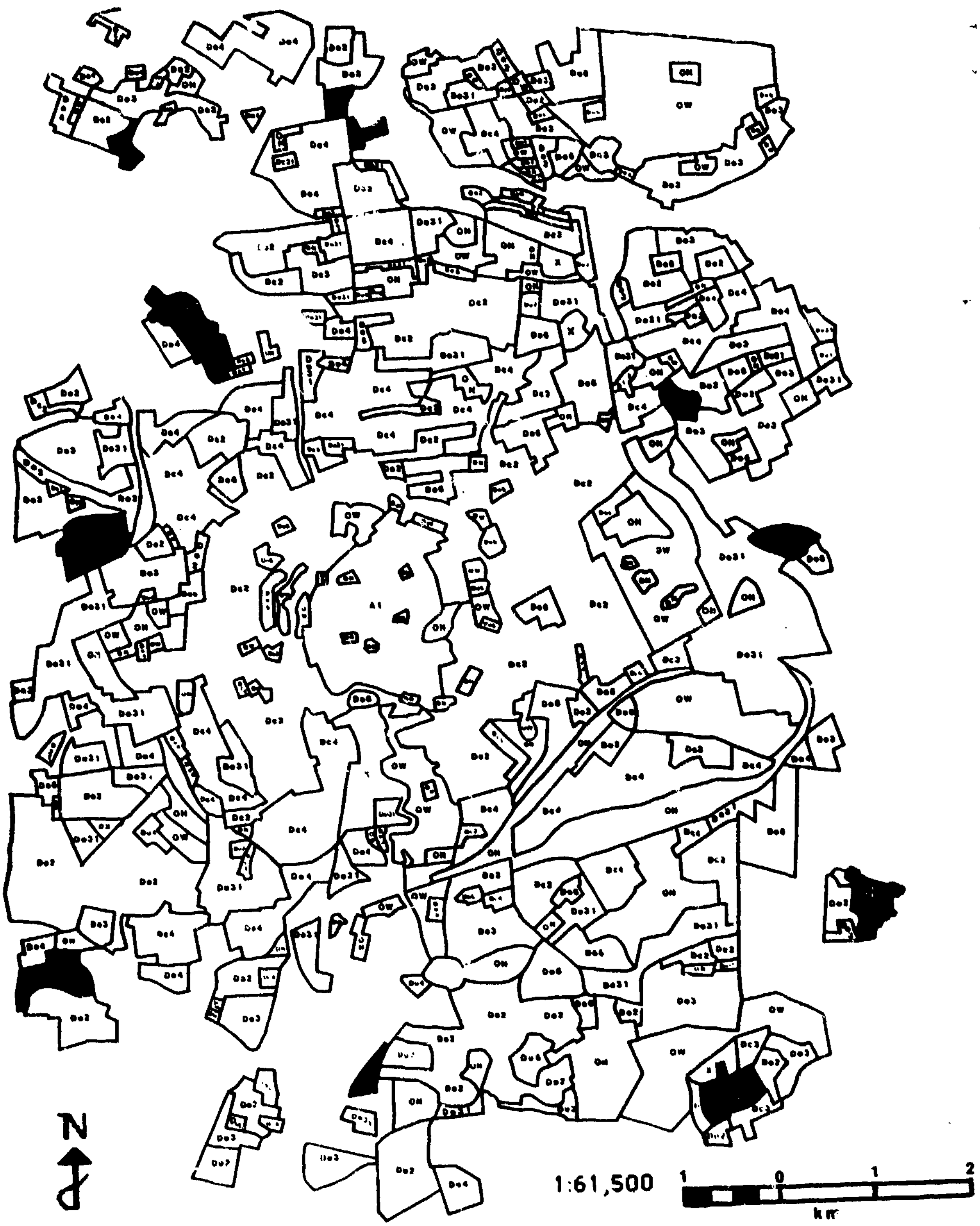
Braunschweig: Apartments, >75% ground coverage (Dc2)



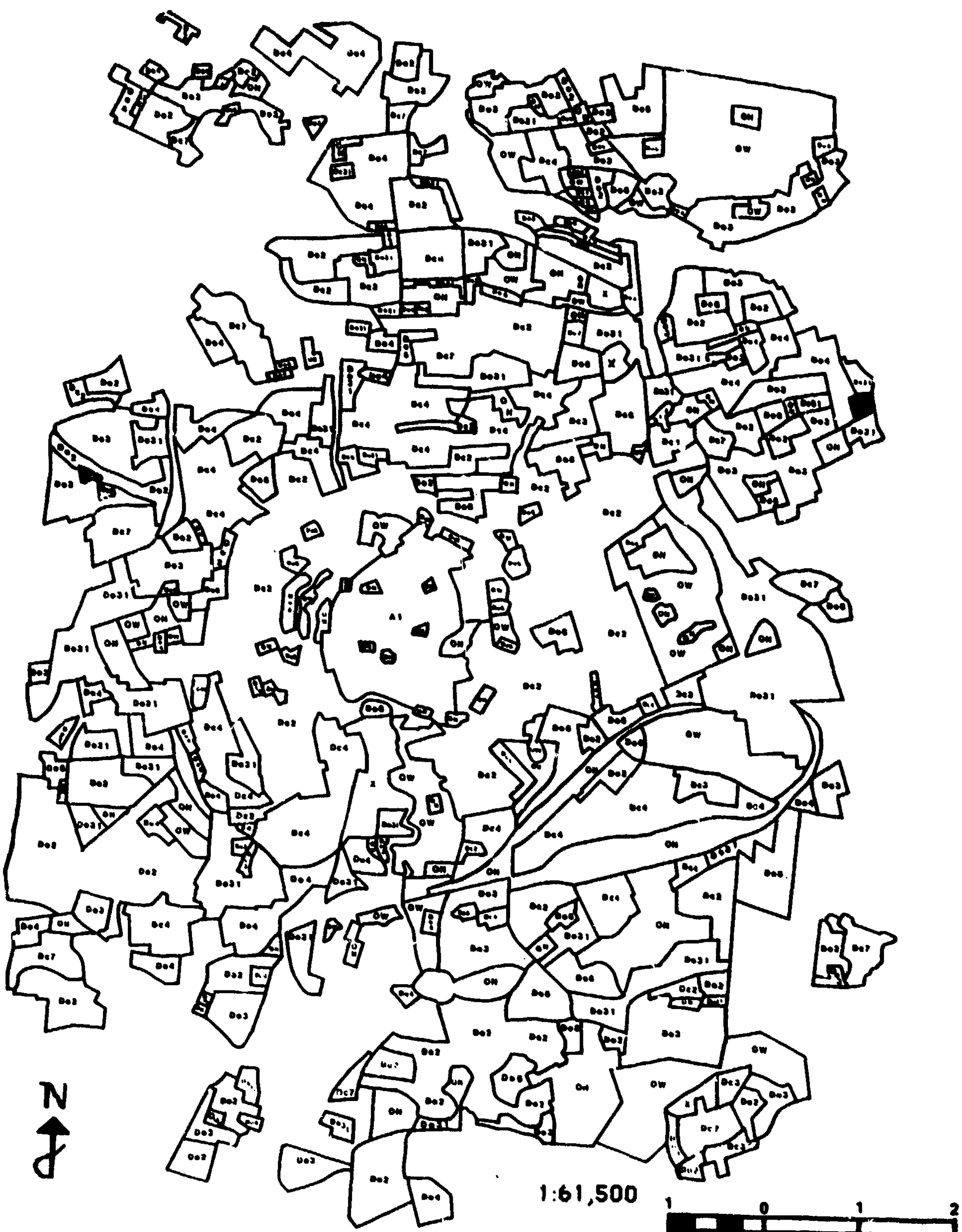
Braunschweig: Houses, >75% ground coverage (Dc3)



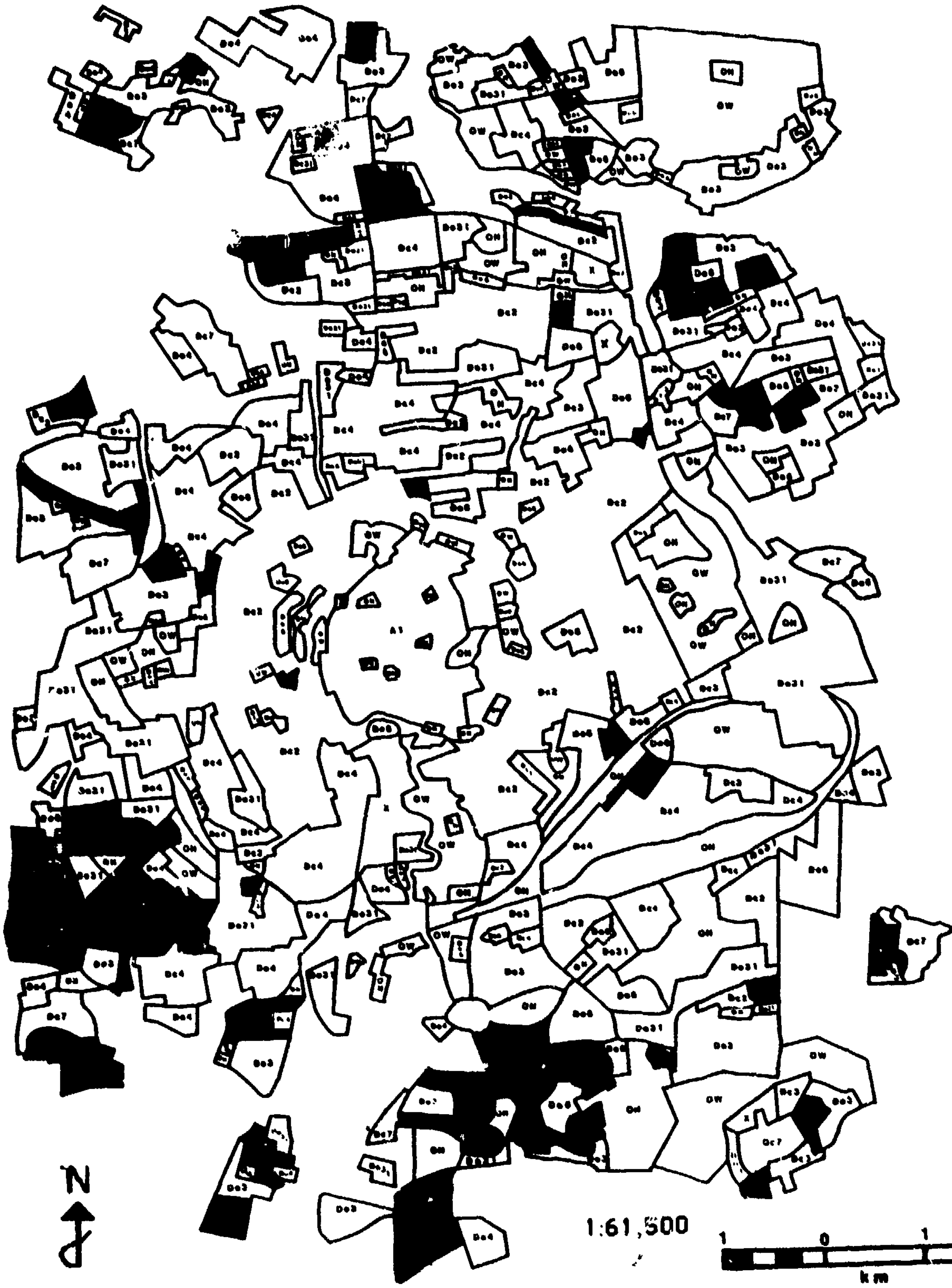
Braunschweig: Industrial/storage, RR or dock-related (Dc4)



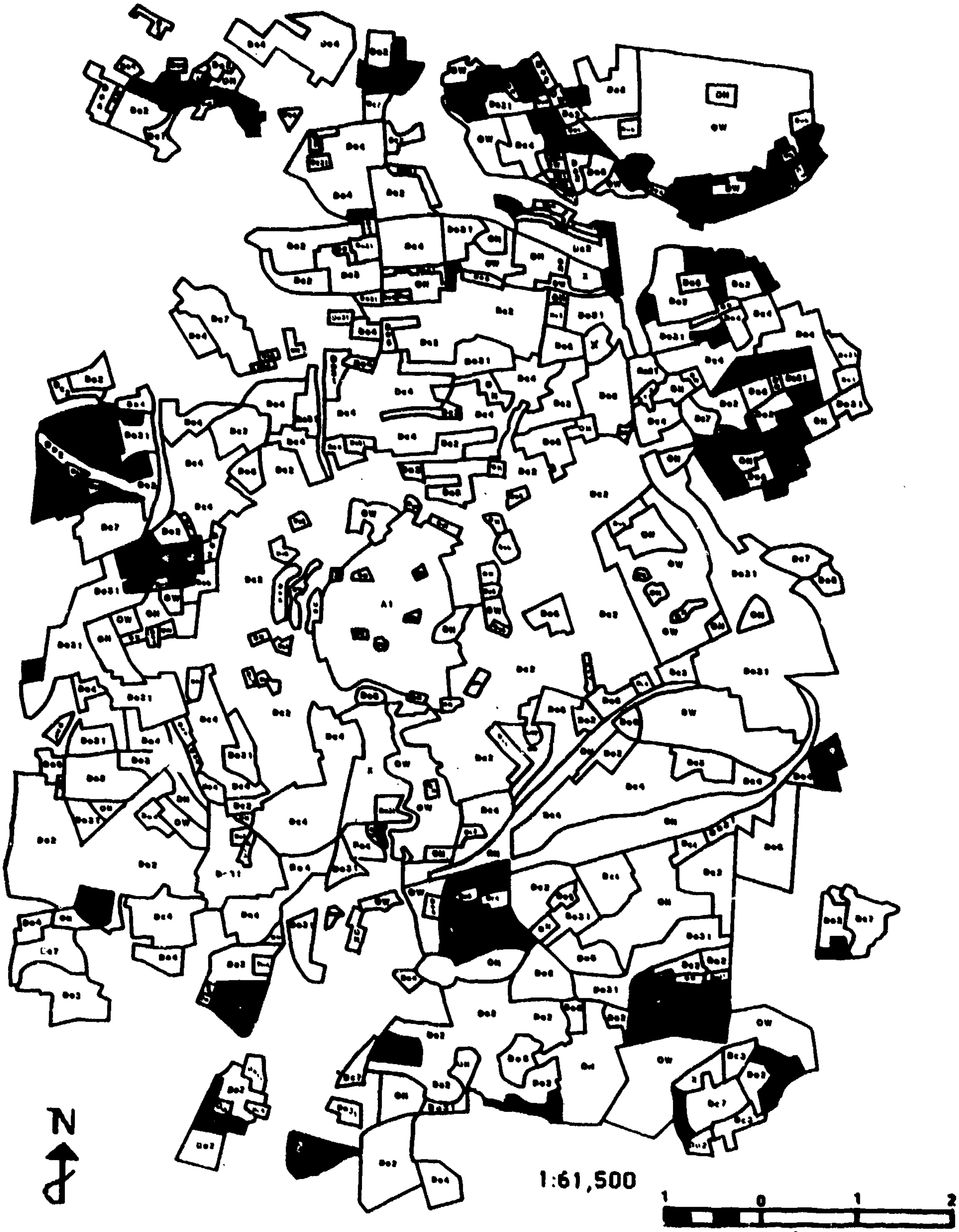
Braunschweig: Engulfed agricultural village (Dc7)



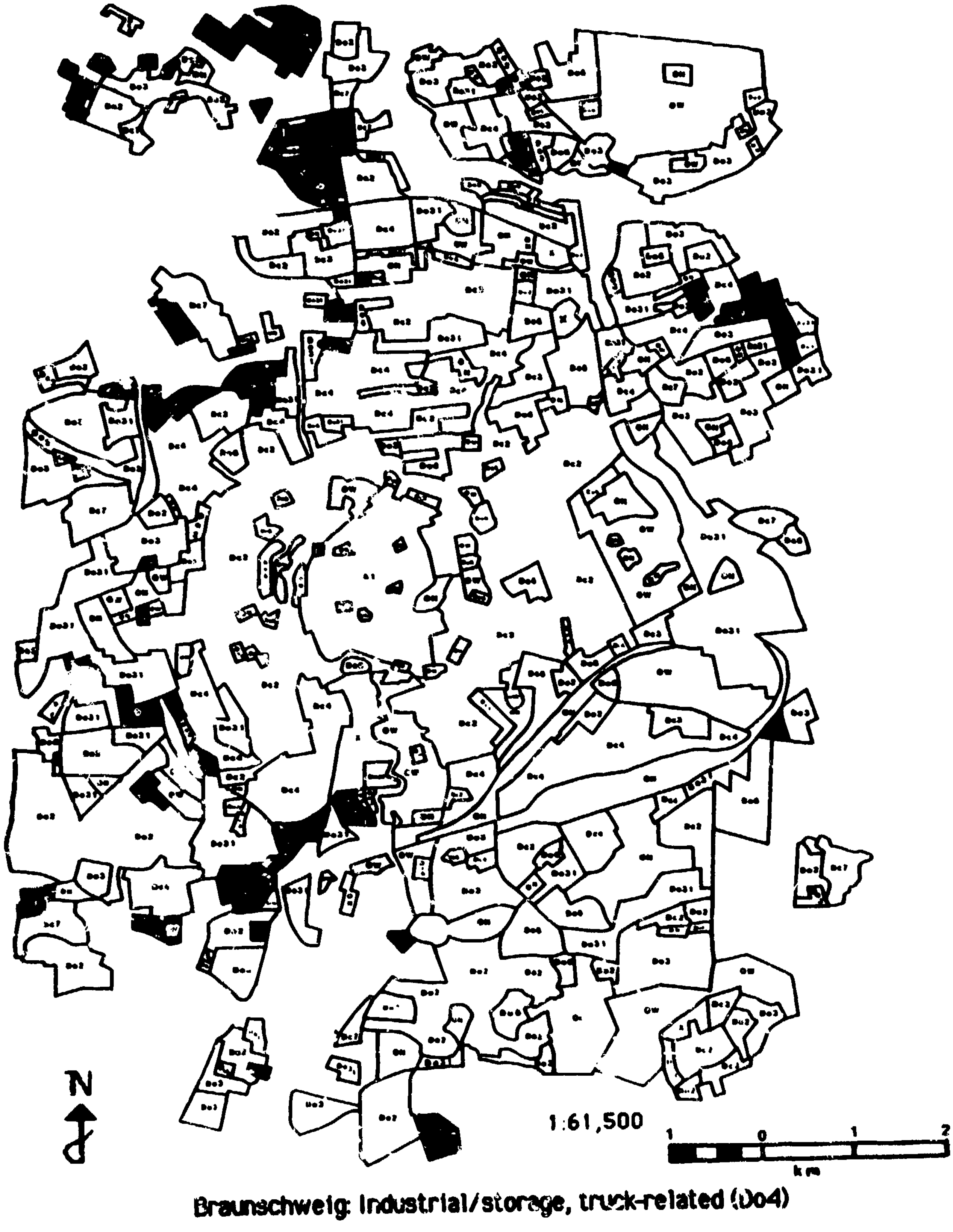
Braunschweig: Shopping Centers (Do1)



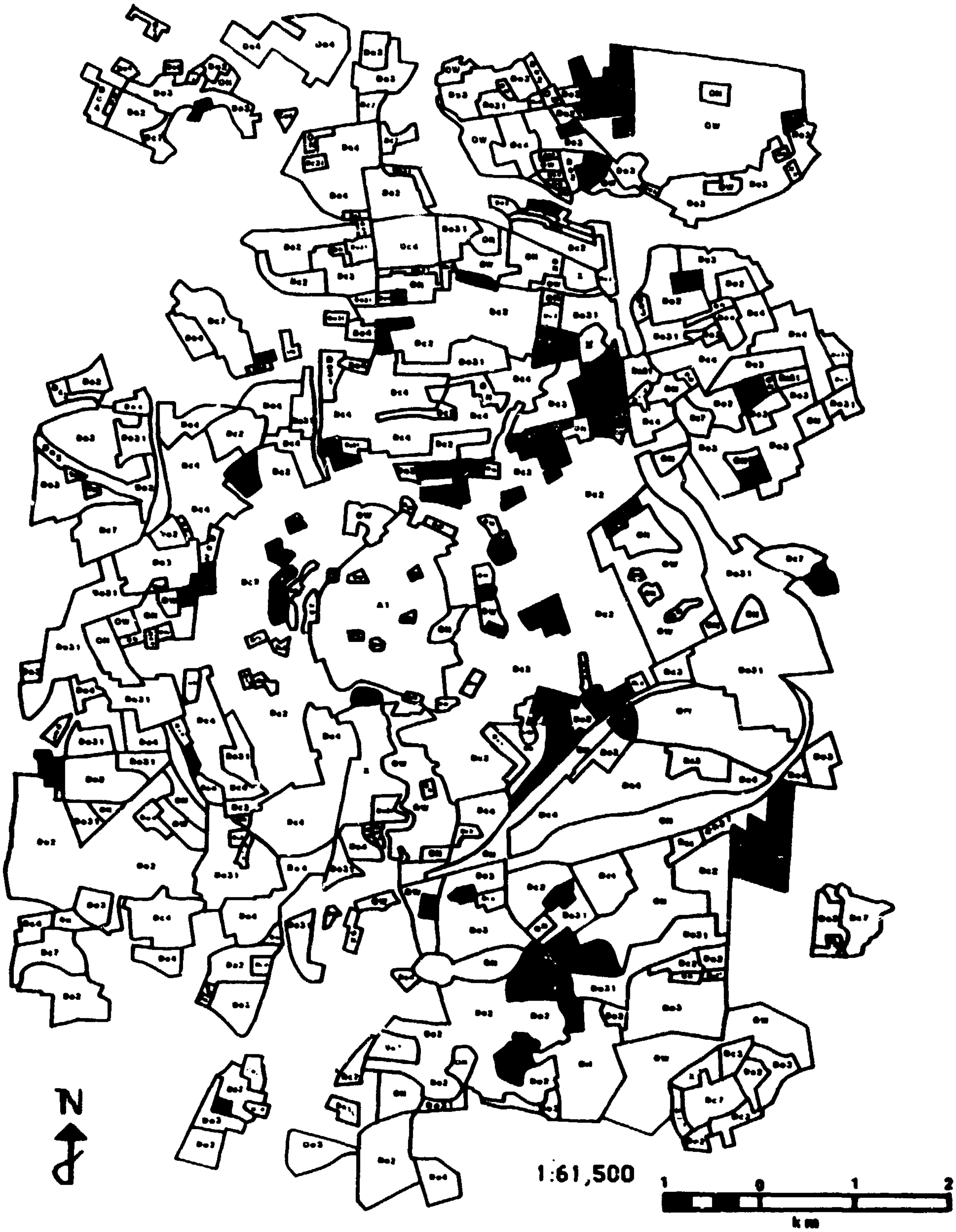
Braunschweig: Apartments, <75% ground coverage (Do2)



Braunschweig: Houses, <75% ground coverage (Do3)



Braunschweig: Industrial/storage, truck-related (Do4)

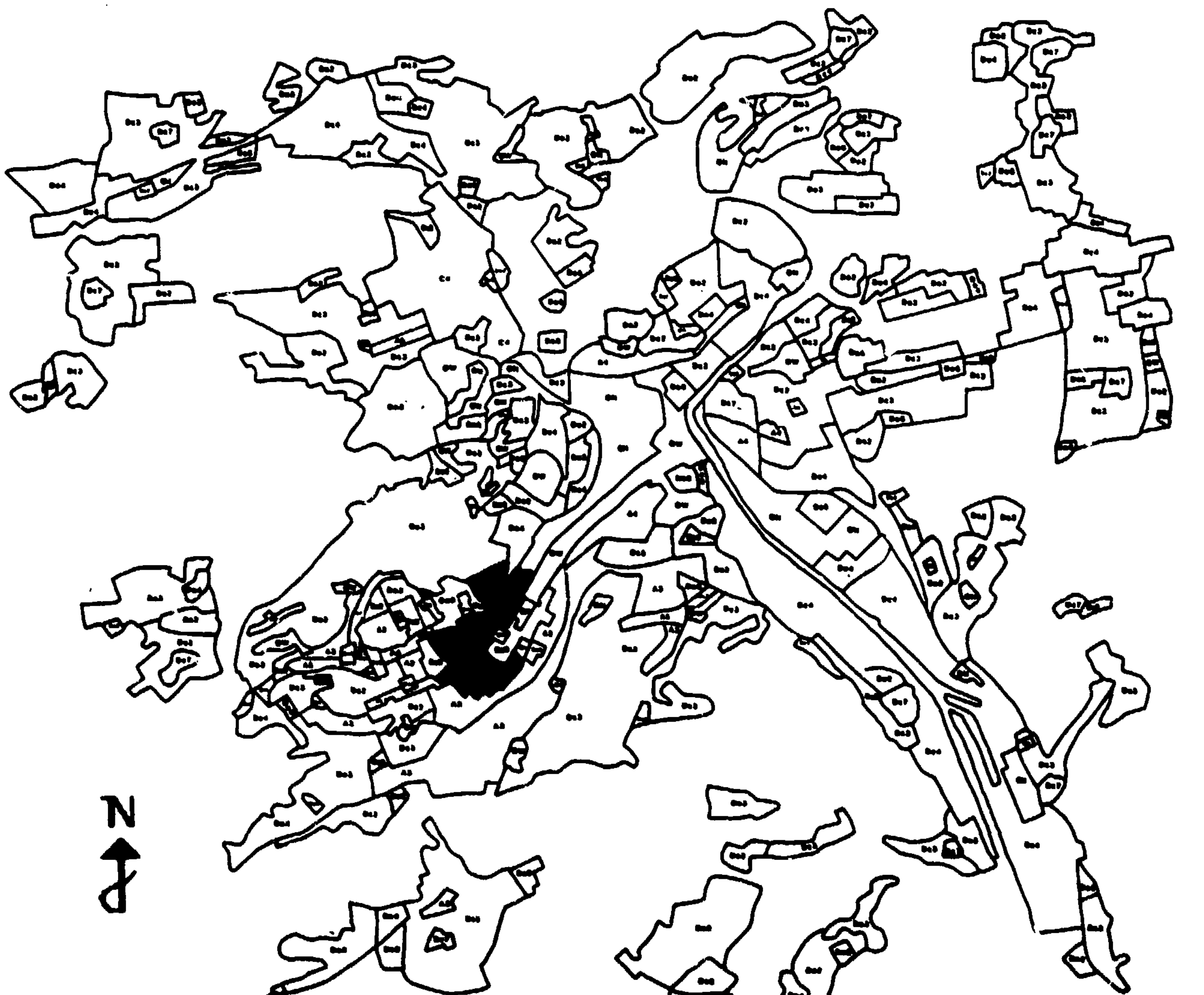


Braunschweig: Administrative/cultural (Do6)

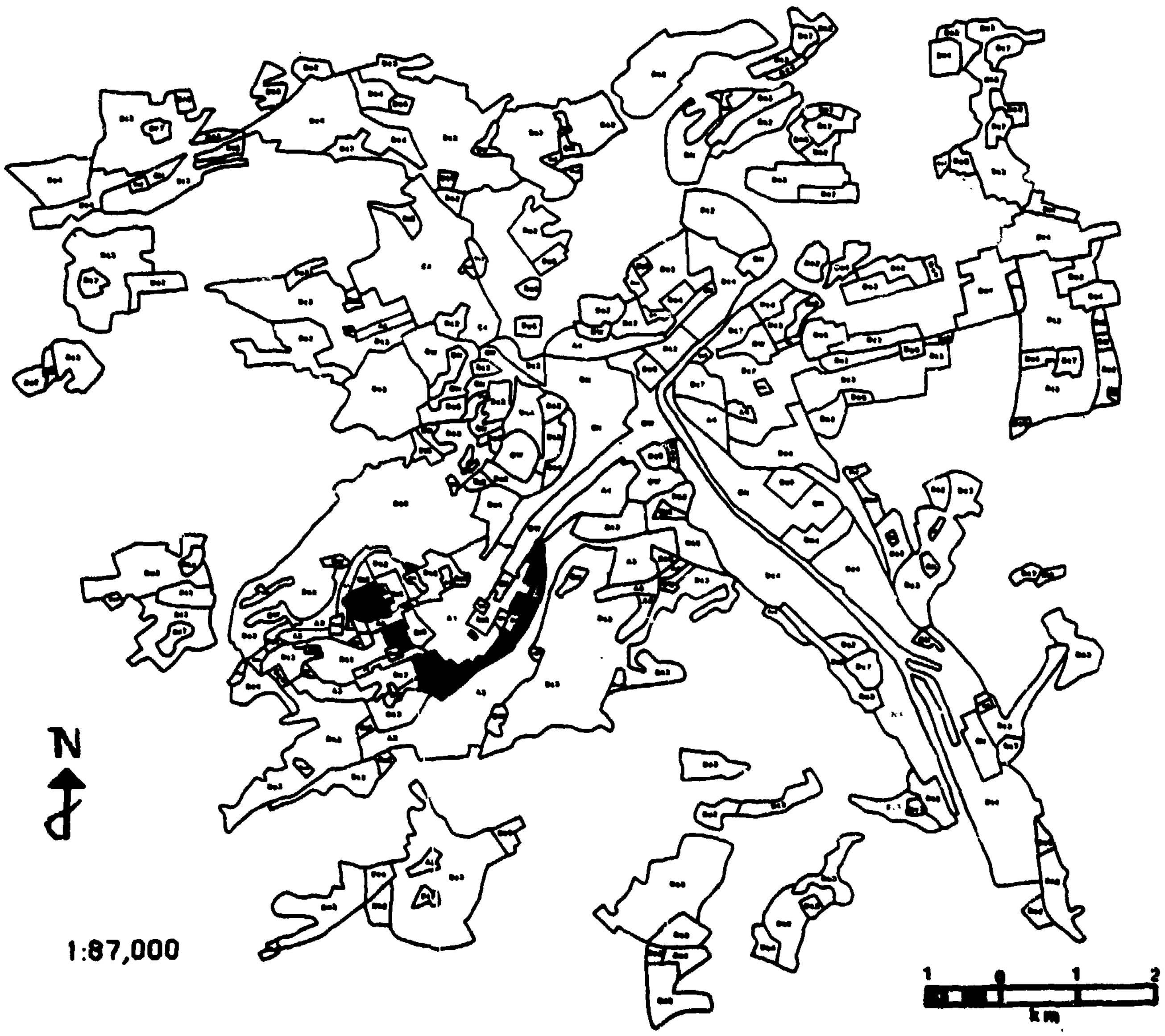
Braunschweig: Open Space, not built upon (ON)

Braunschweig: Open Space, wooded, not built upon (OW)

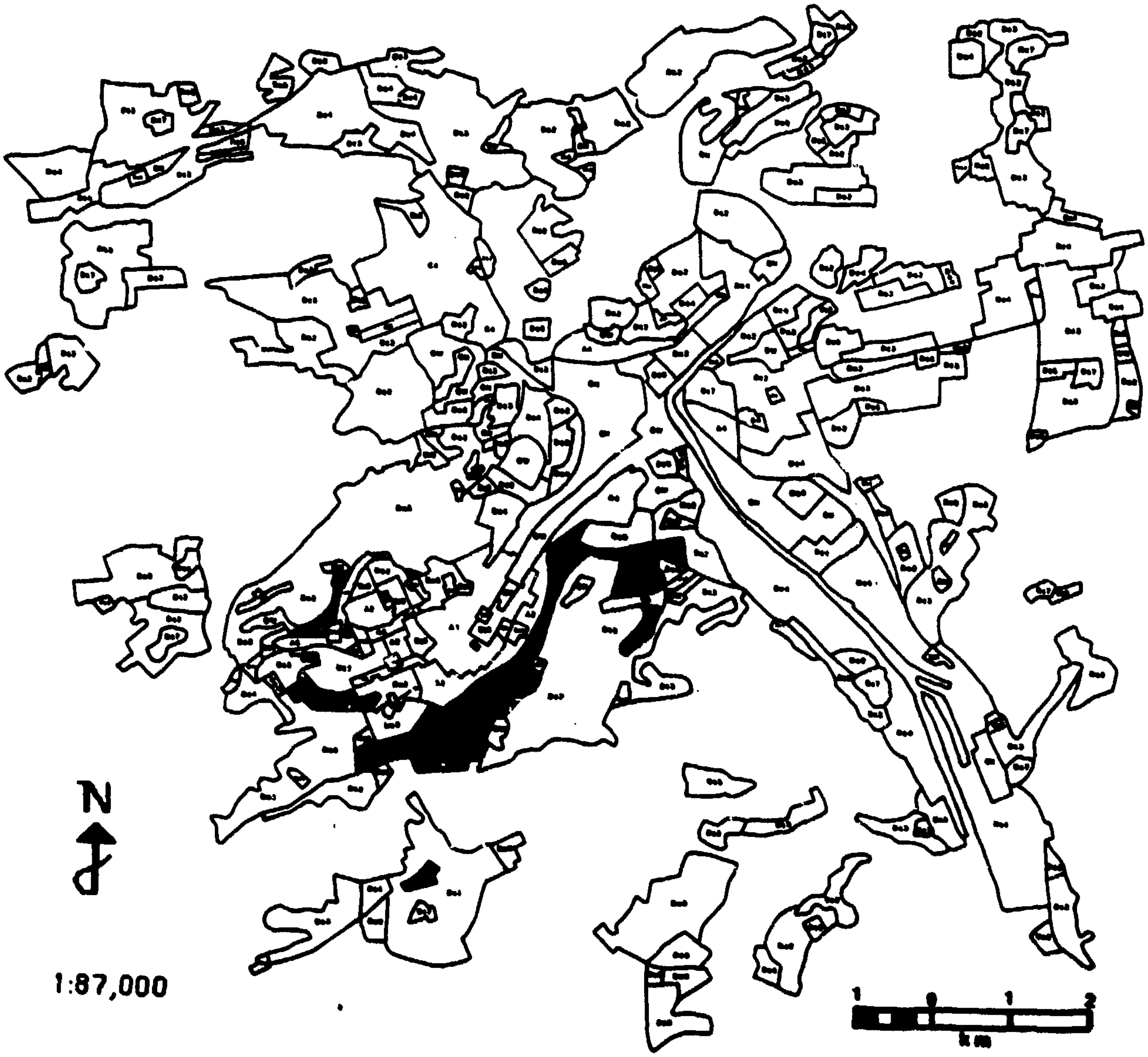
Braunschweig: Leased garden areas [with huts] (Do31)



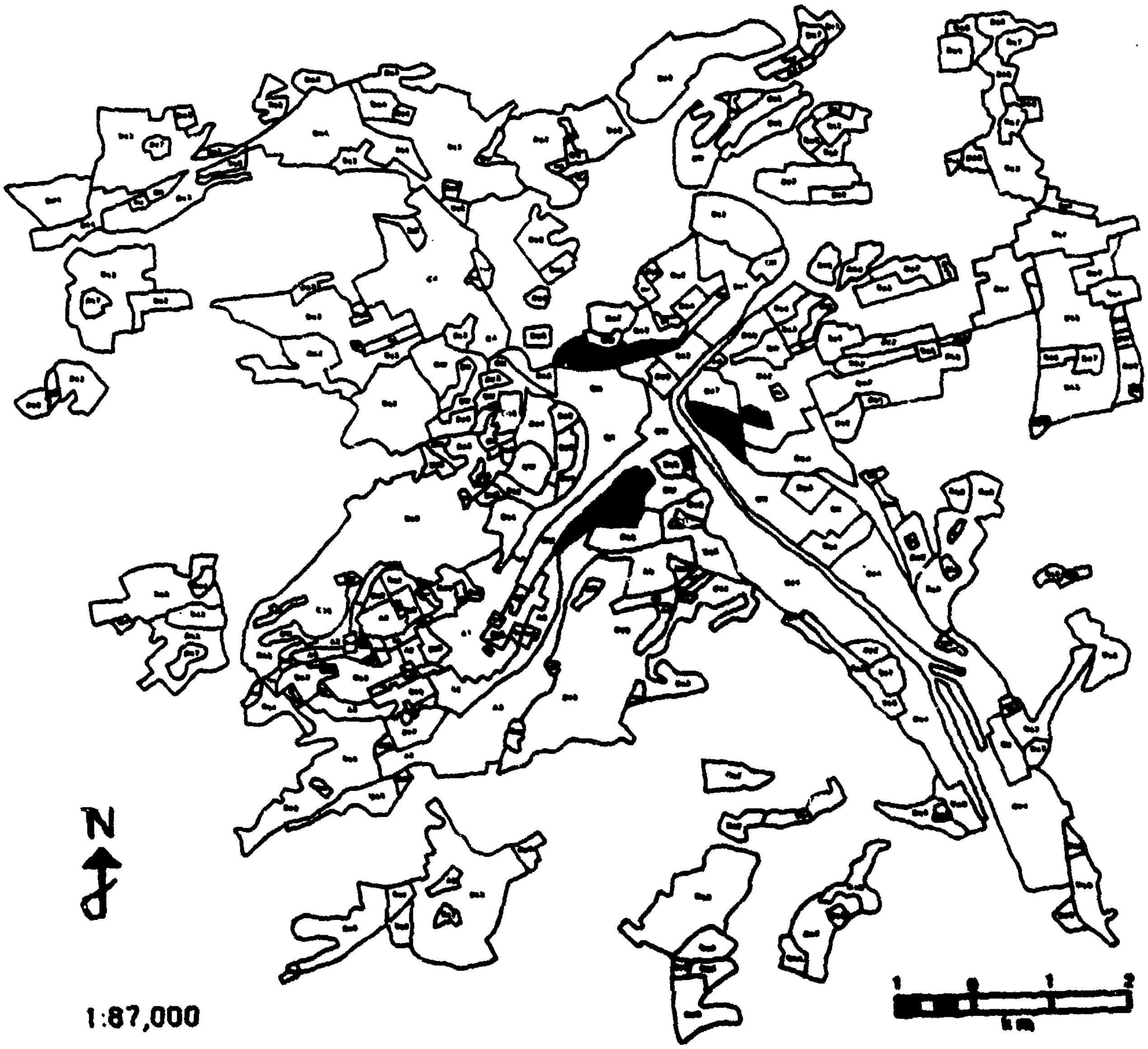
Stuttgart: Core Area (A1)



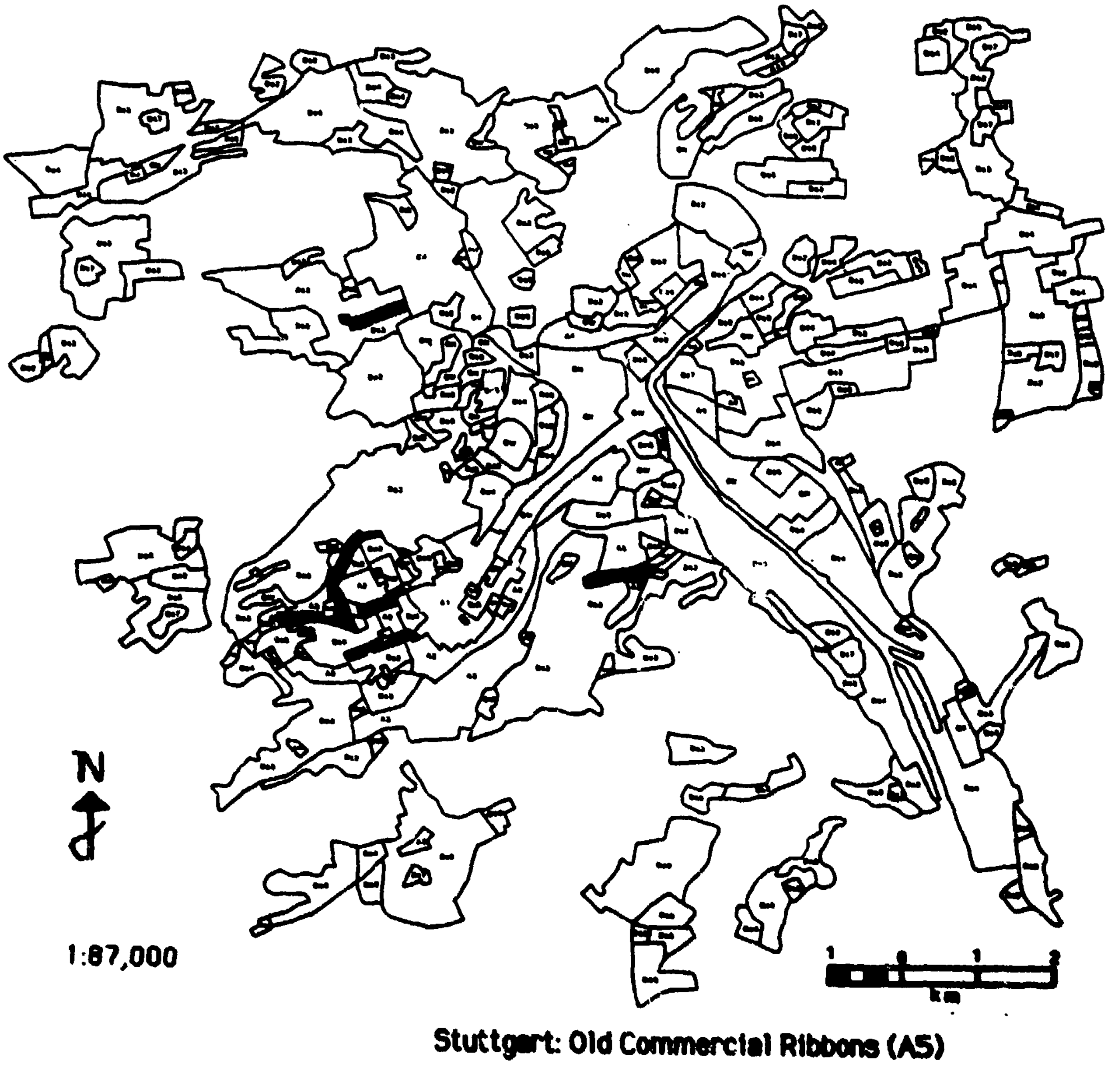
Stuttgart: Apartments/hotels, core periphery (A2)



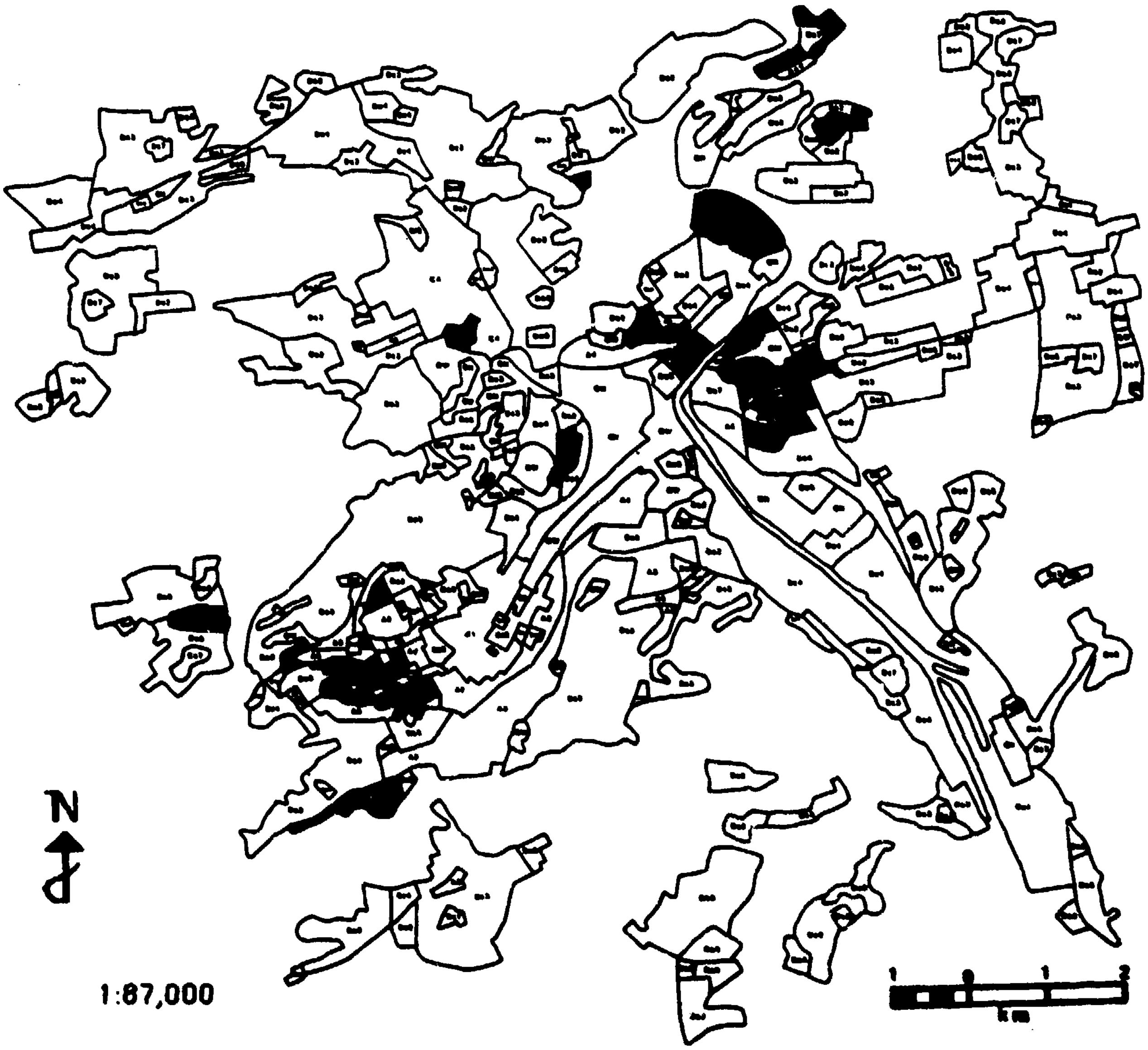
Stuttgart: Apartments/row houses (A3)



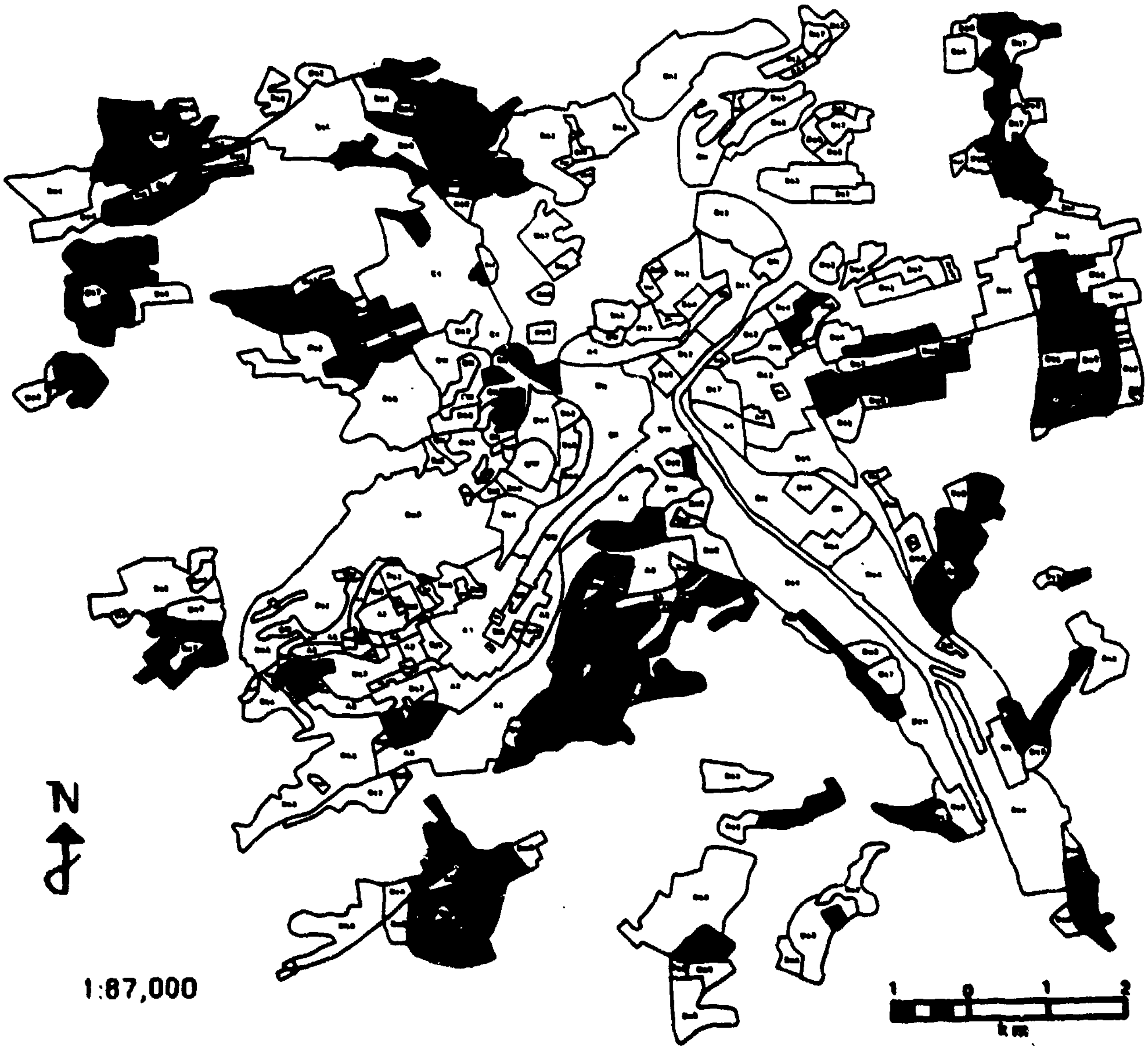
Stuttgart: Industrial/storage, full urban form (A4)



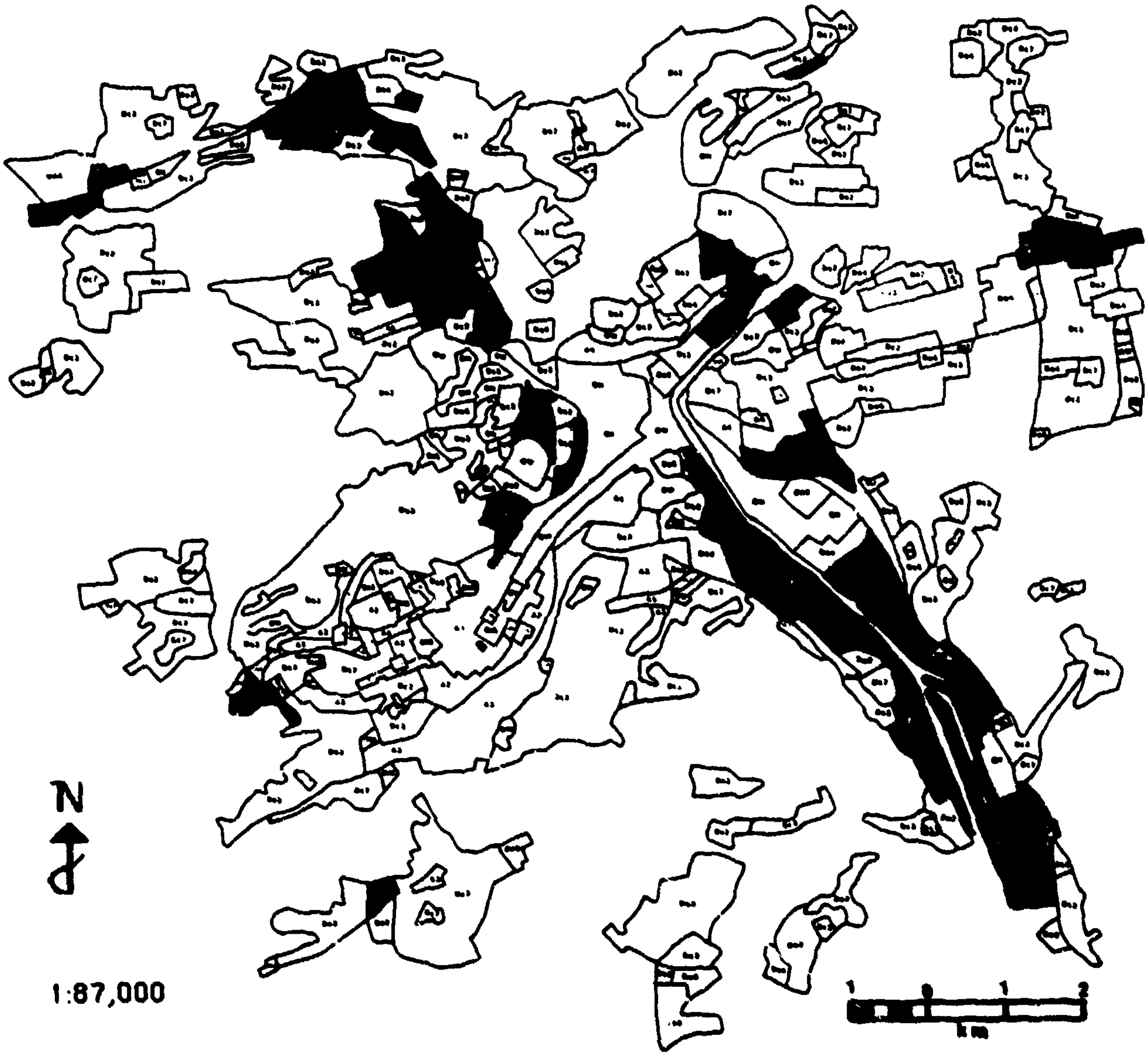
Stuttgart: Old Commercial Ribbons (A5)



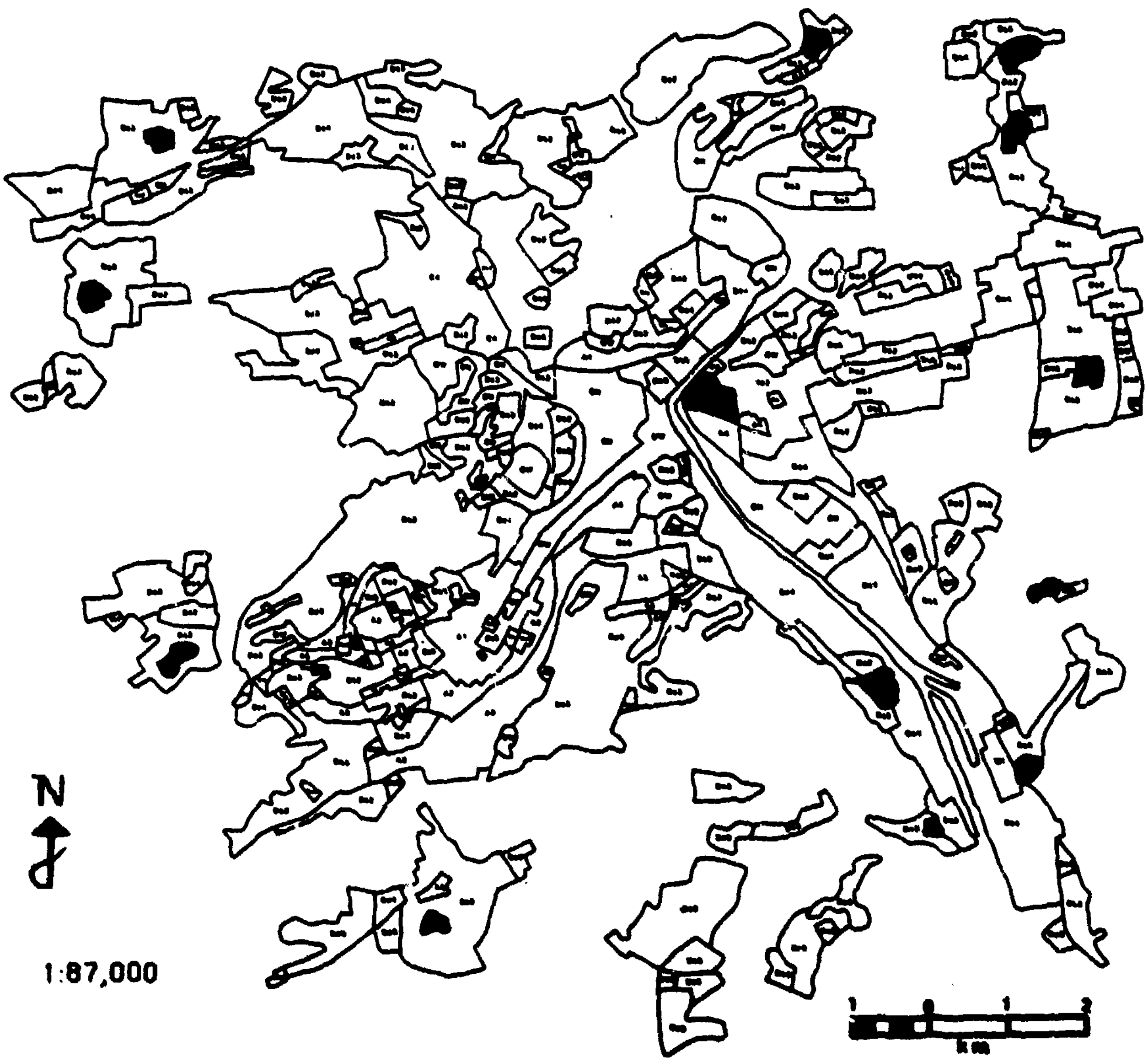
Stuttgart: Apartments, >75% ground coverage (Dc2)



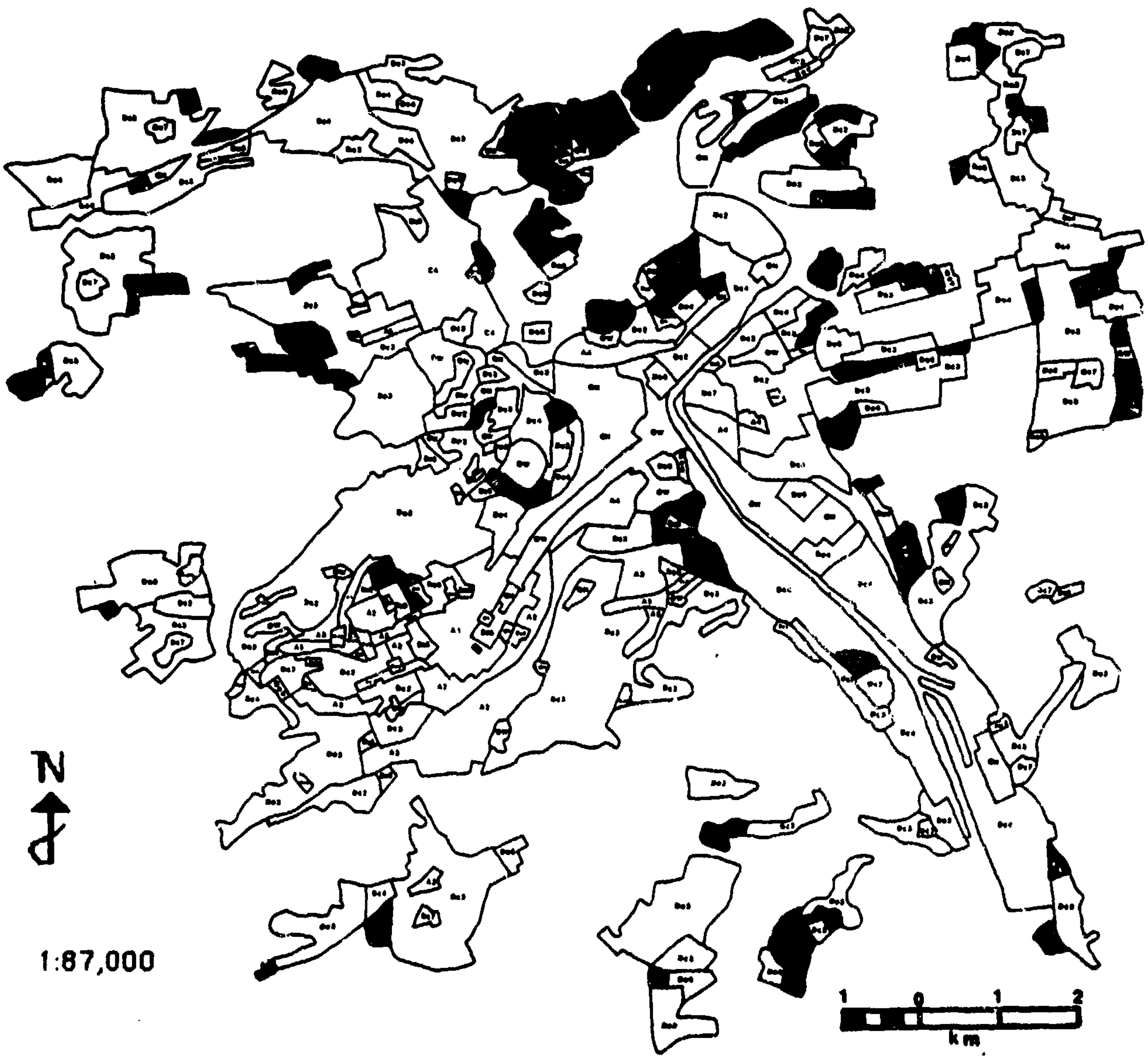
Stuttgart: Houses, >75% ground coverage (Dc3)



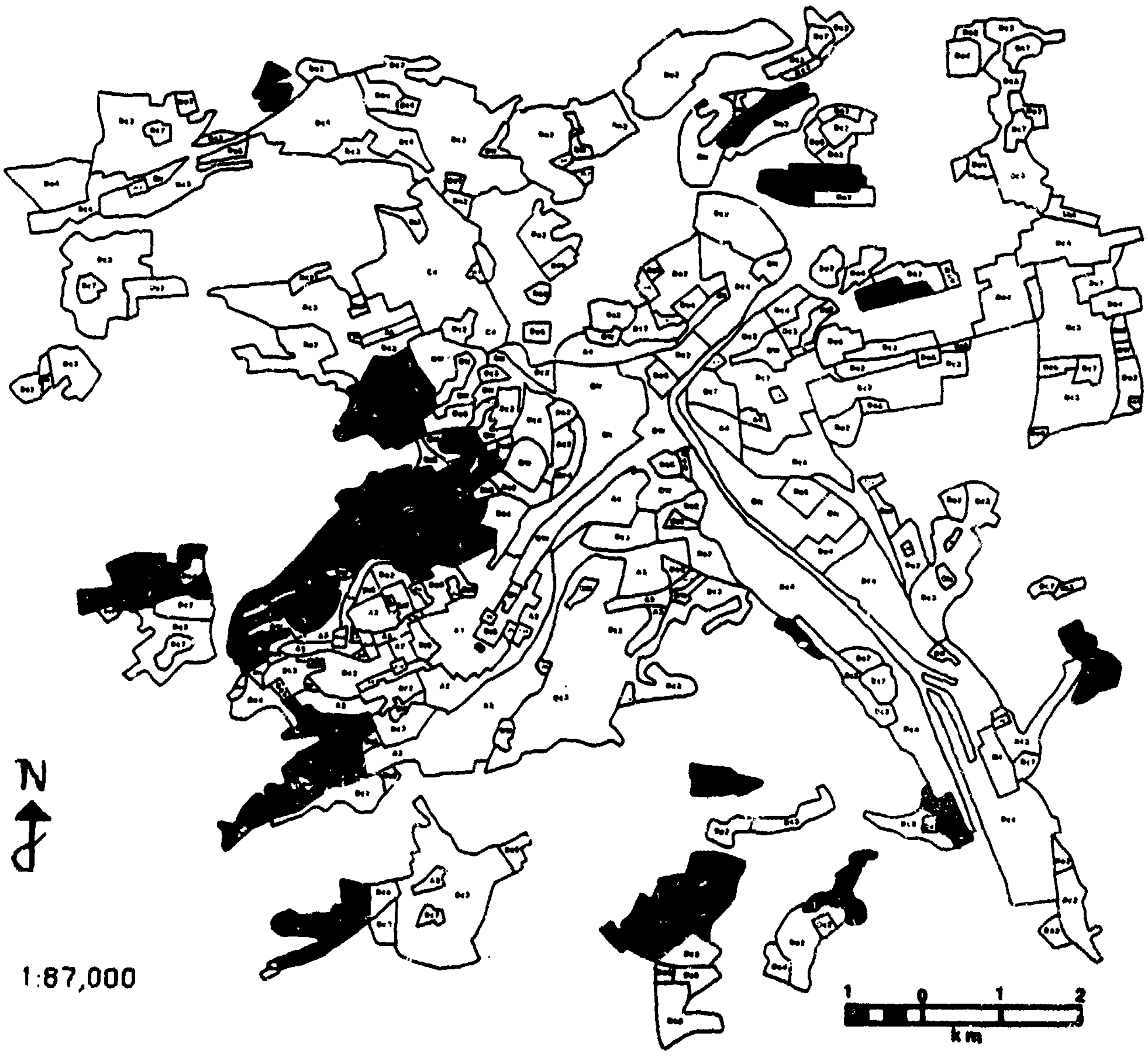
Stuttgart: Industrial/storage, RR or dock-related (Dc4)



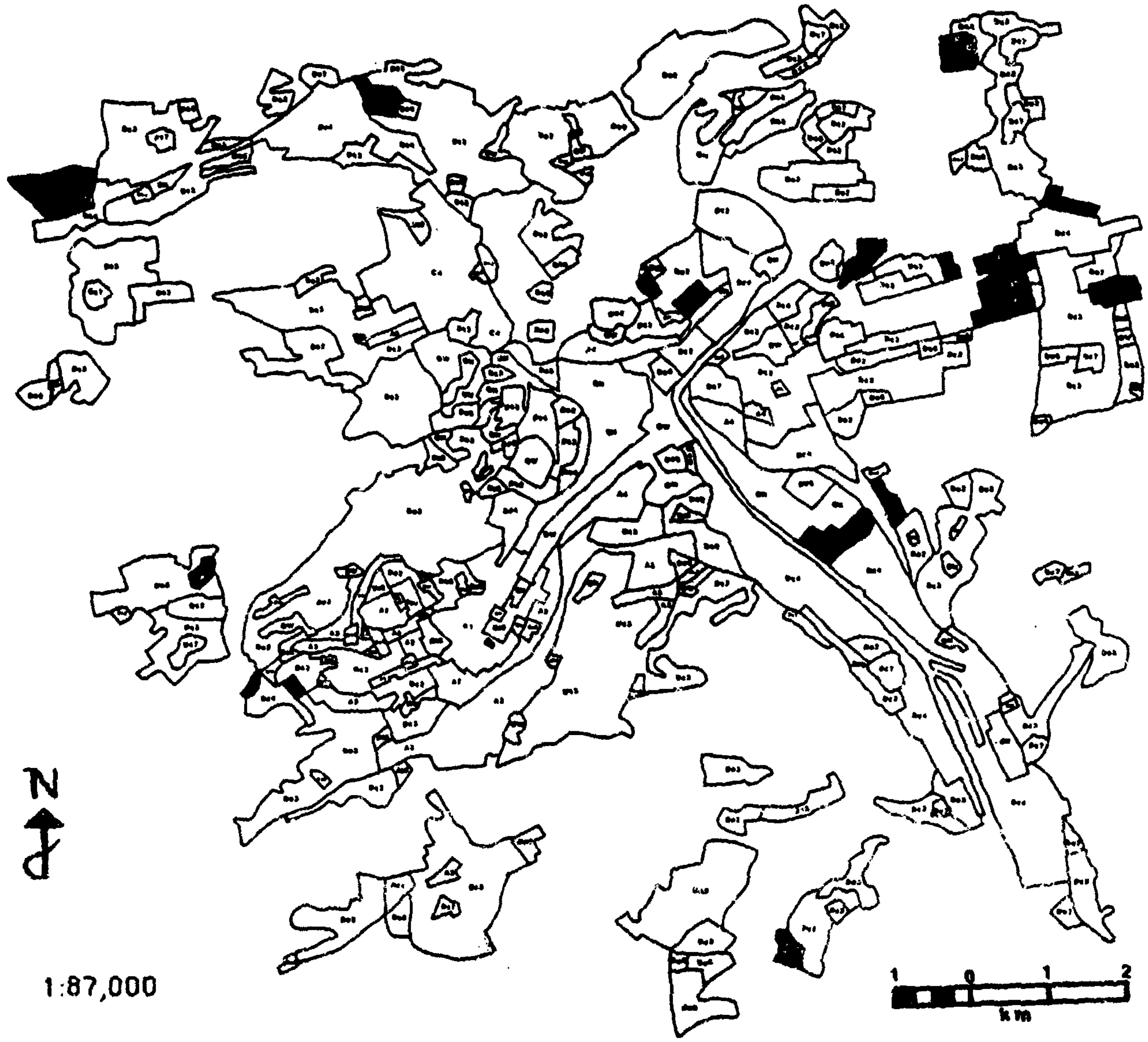
Stuttgart: Engulfed agricultural village (Dc7)



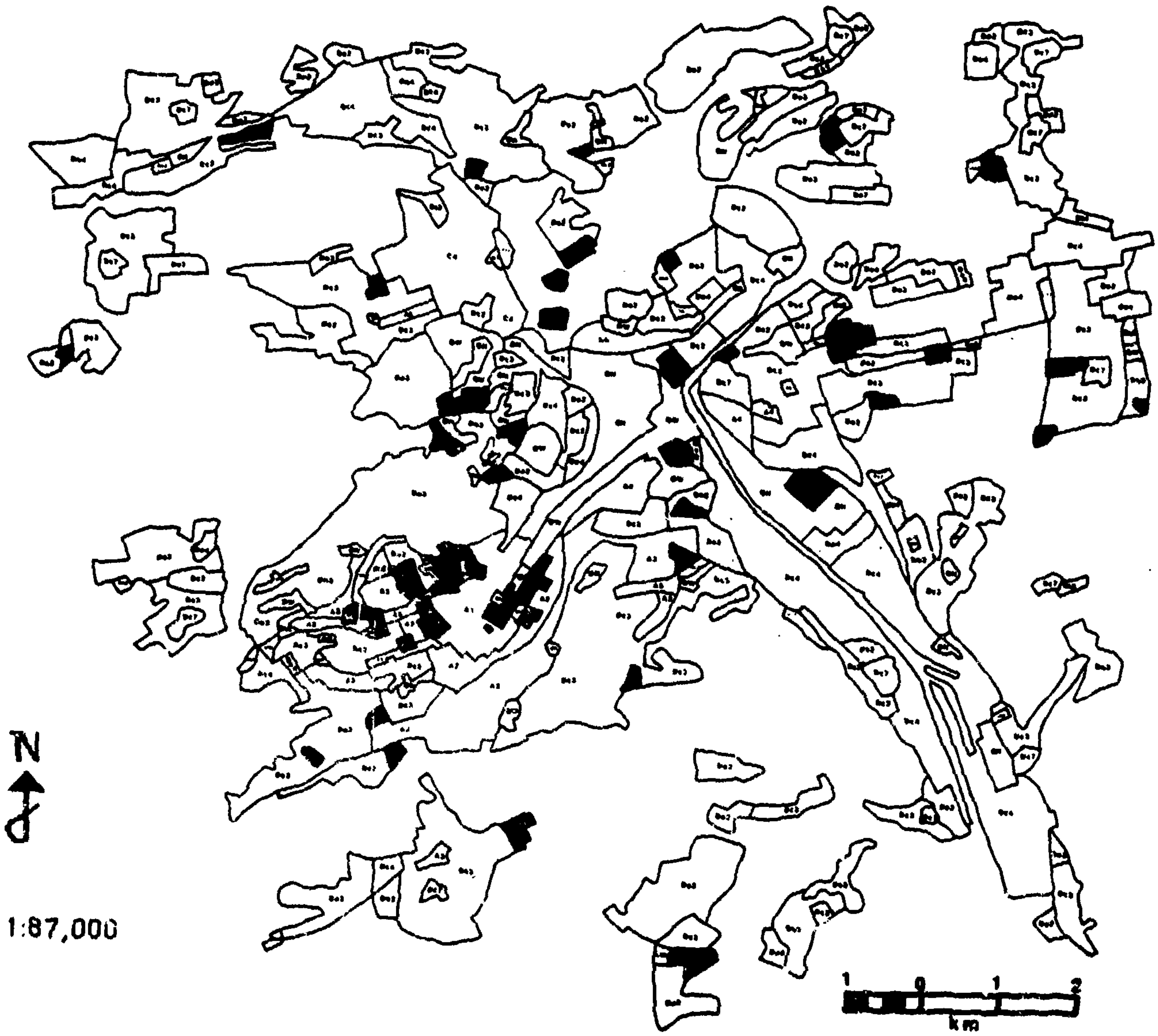
Stuttgart: Apartments, <75% ground coverage (Do2)



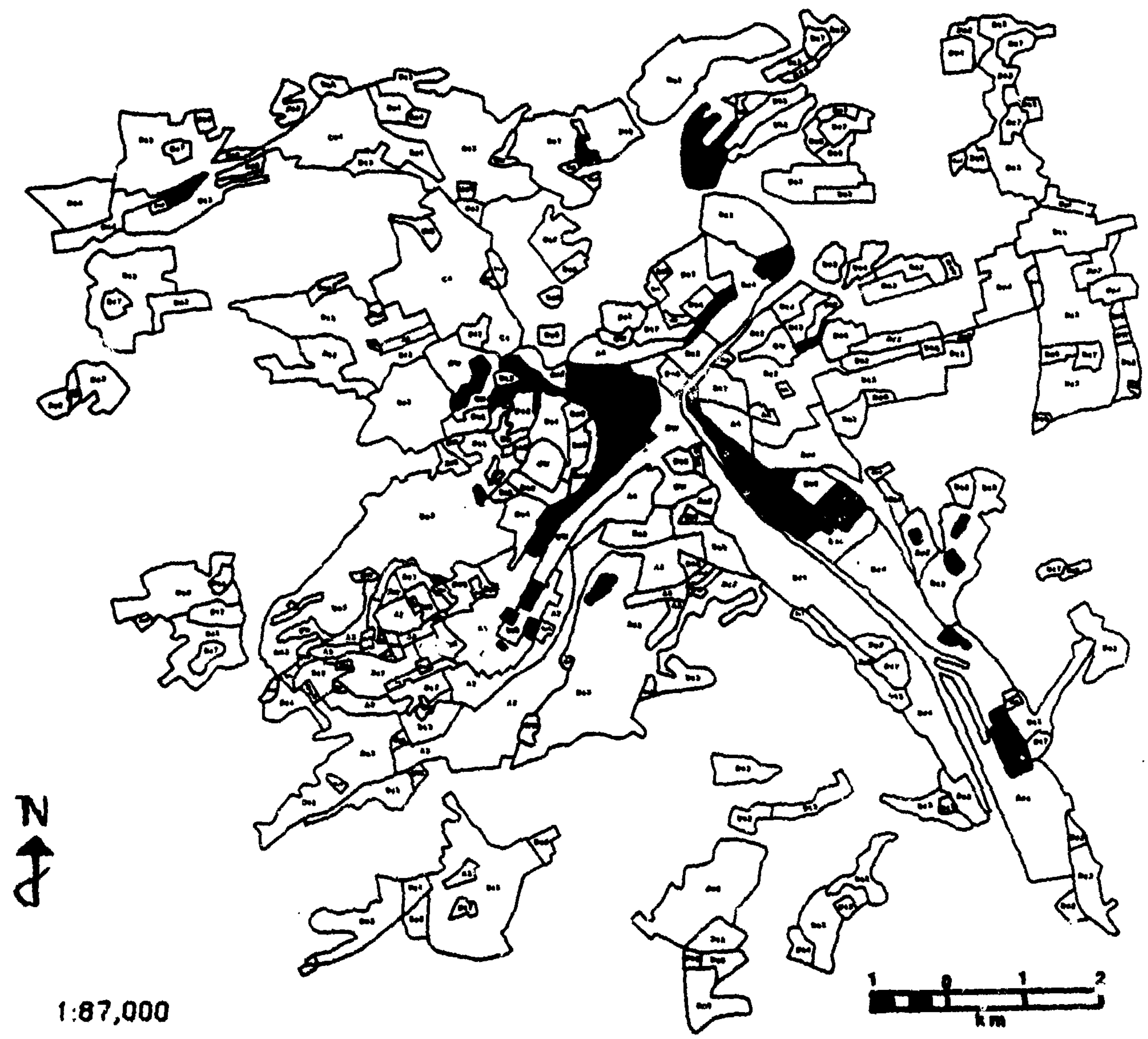
Stuttgart: Houses, <75% ground coverage (Dc3)



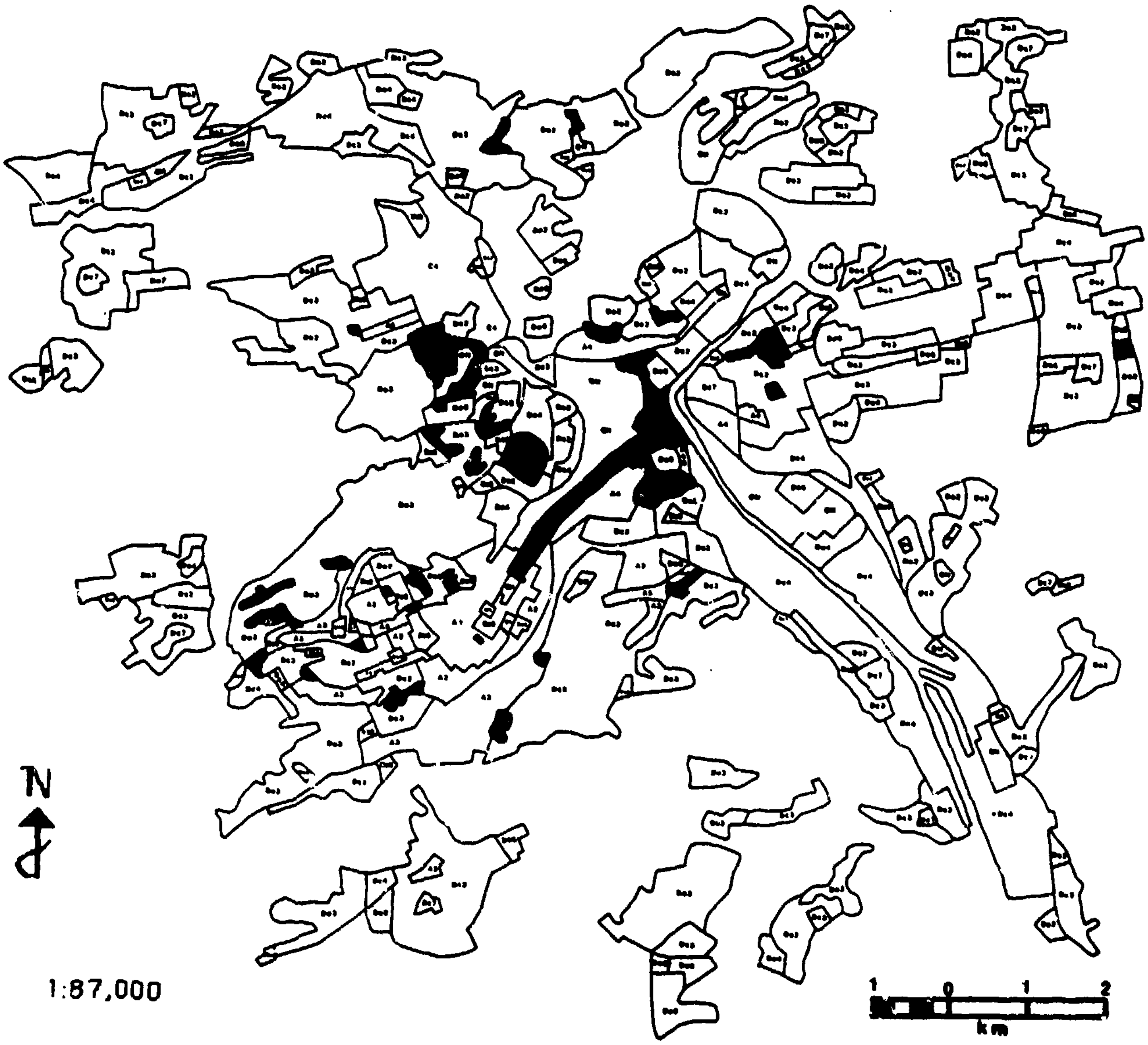
Stuttgart: Industrial/storage, truck-related (Do4)



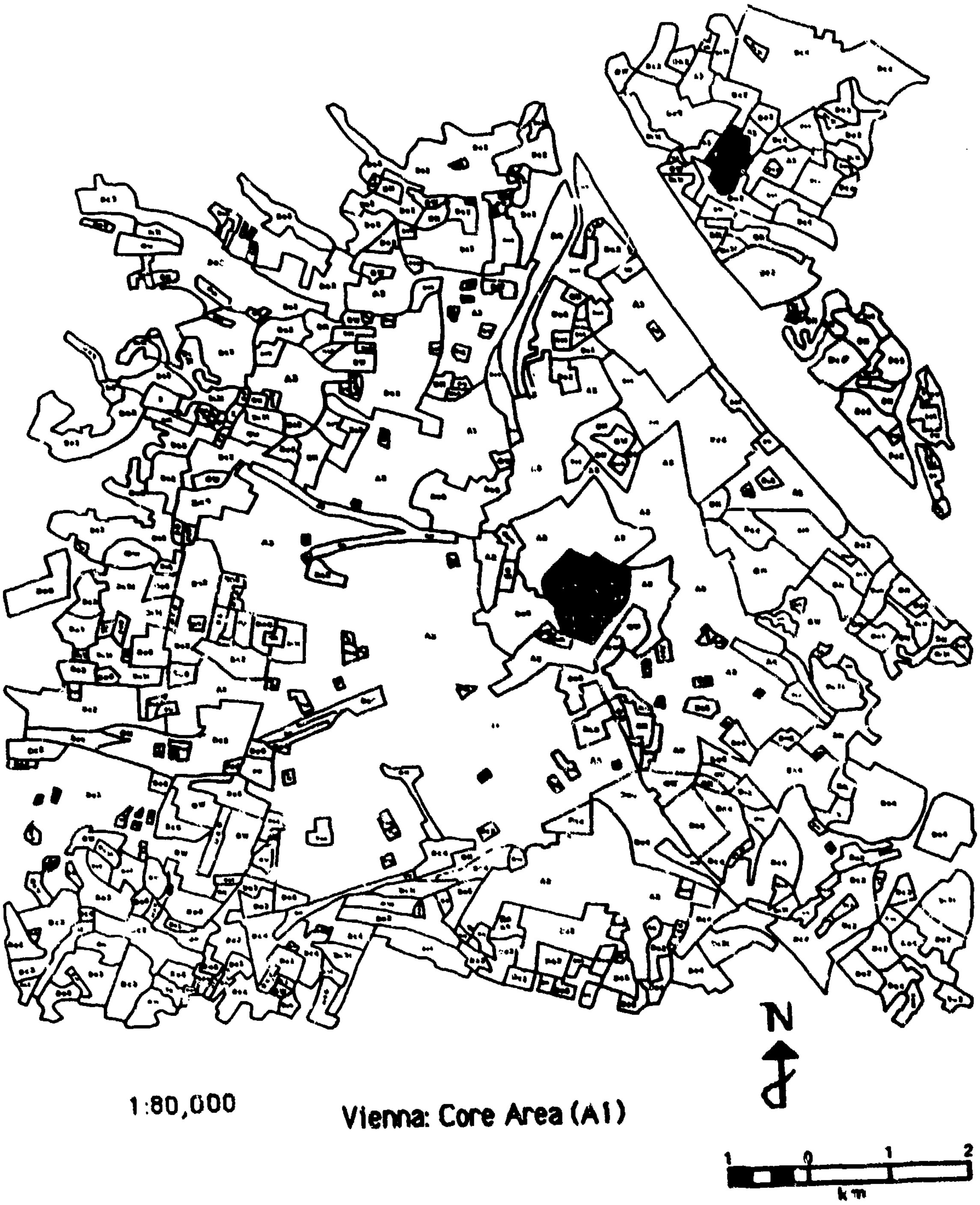
Stuttgart: Administrative/cultural (Do6)



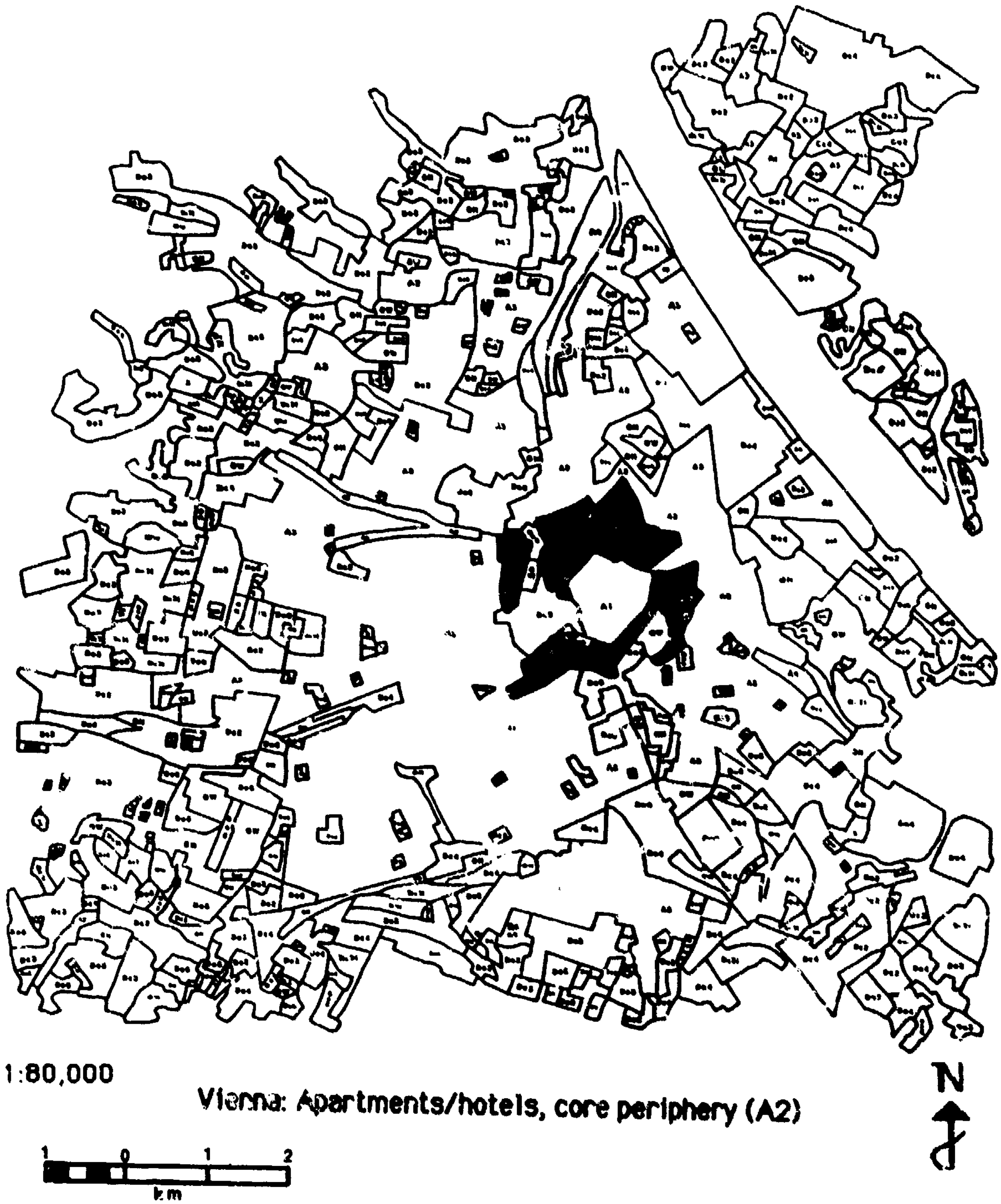
Stuttgart: Open Space, not built upon (ON)



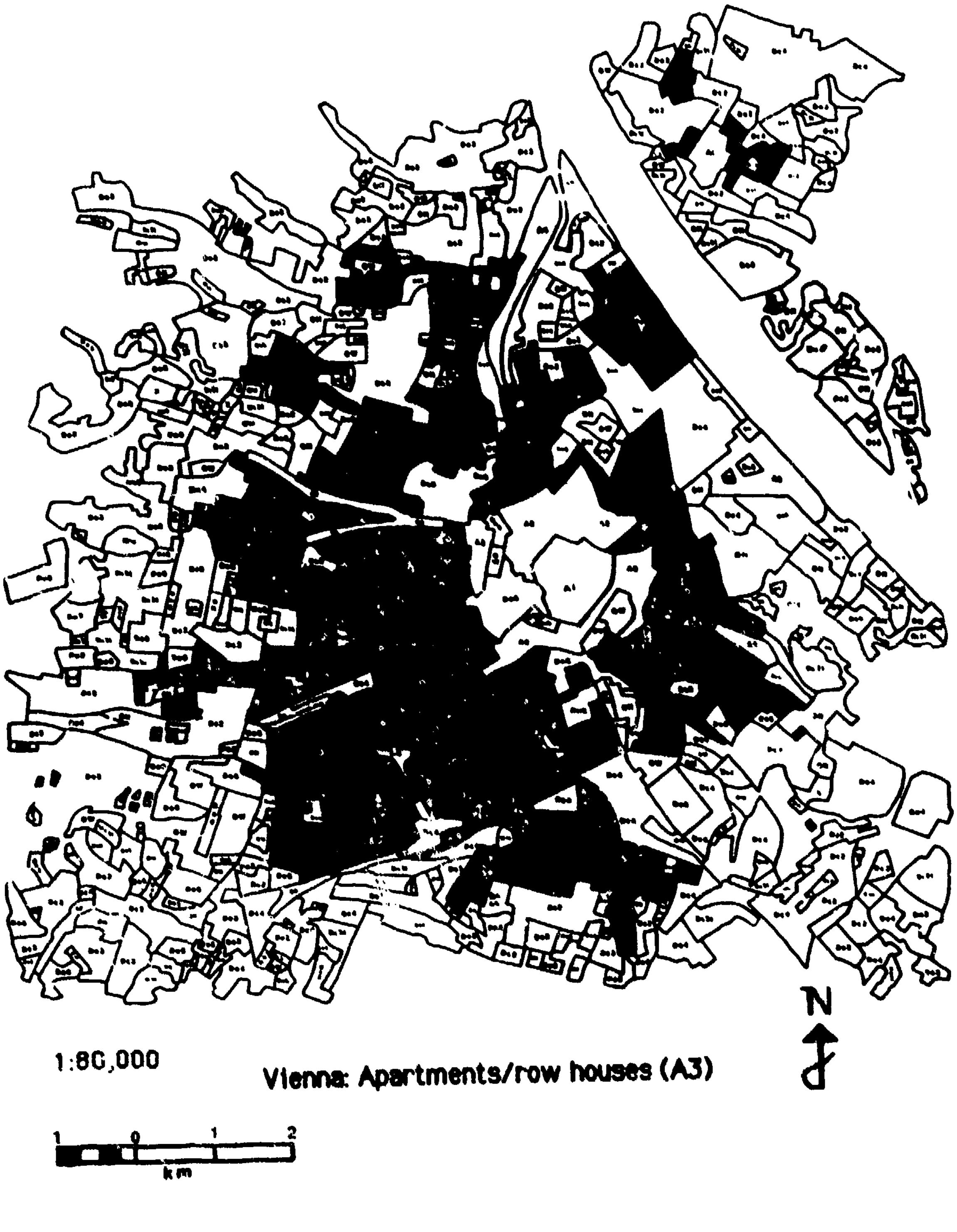
Stuttgart: Open Space, wooded, not built upon (OW)



1:80,000 Vienna: Core Area (A1)

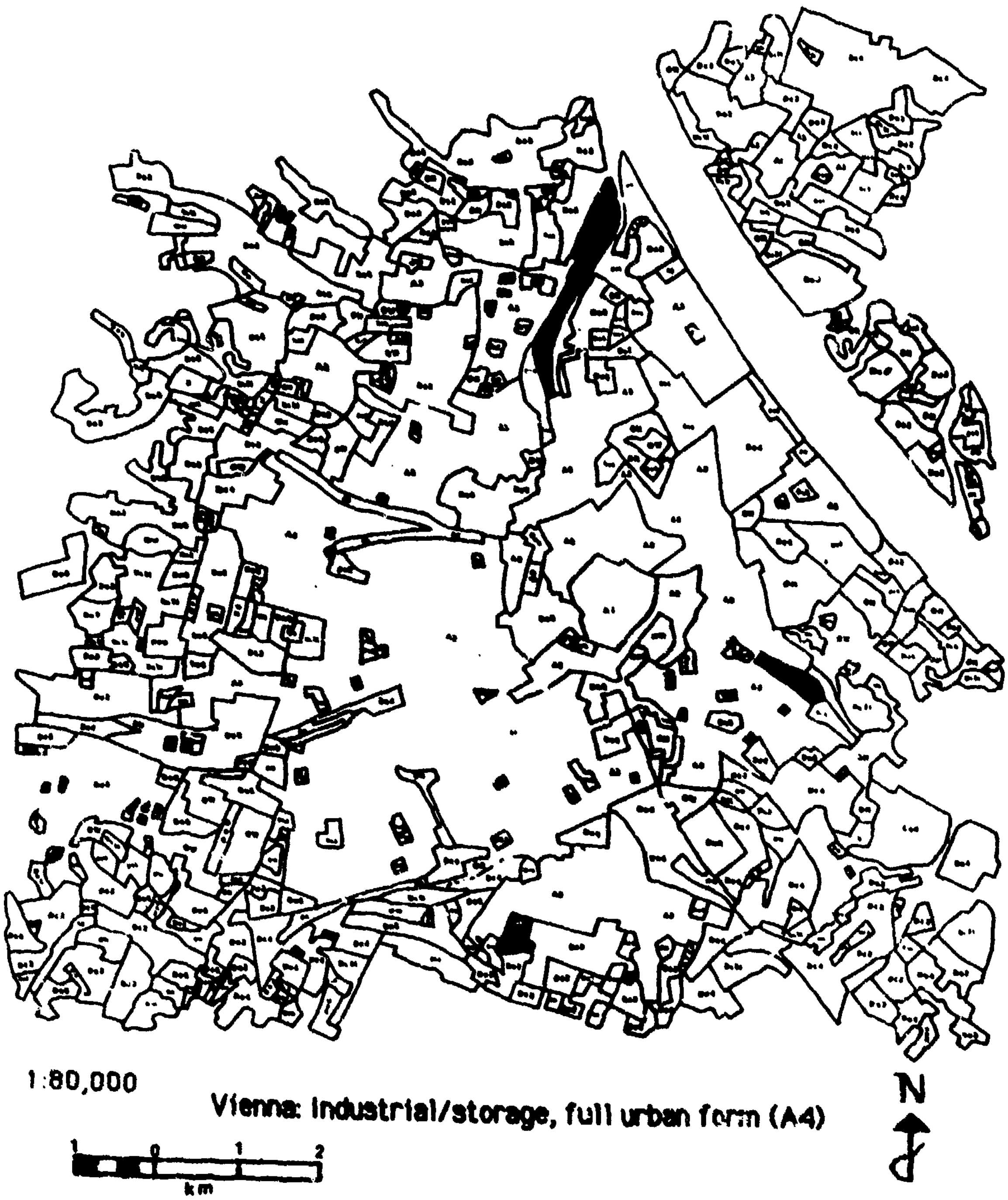


Vienna: Apartments/hotels, core periphery (A2)

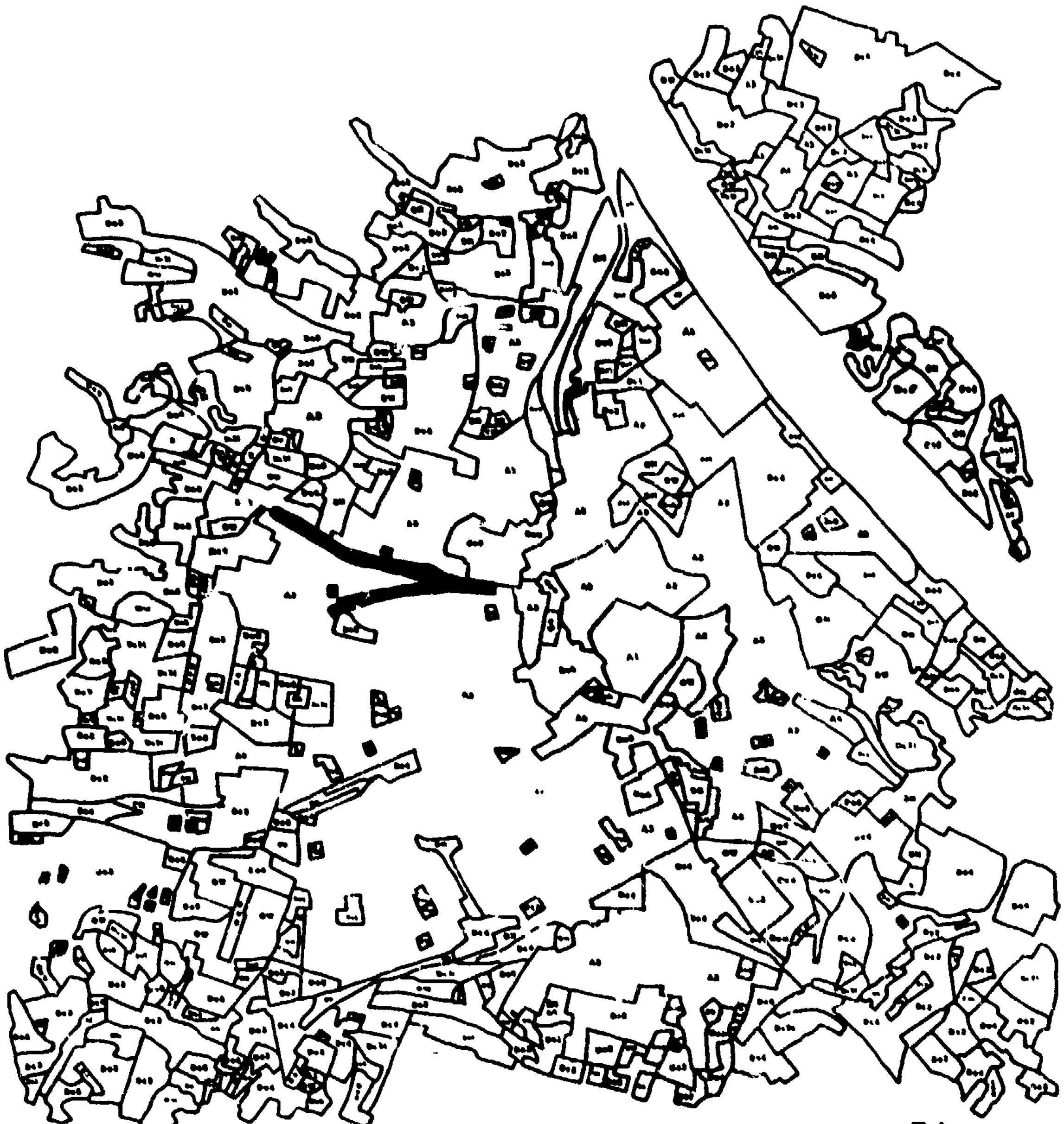


1:80,000

Vienna: Apartments/row houses (A3)



Vienna: industrial/storage, full urban form (A4)



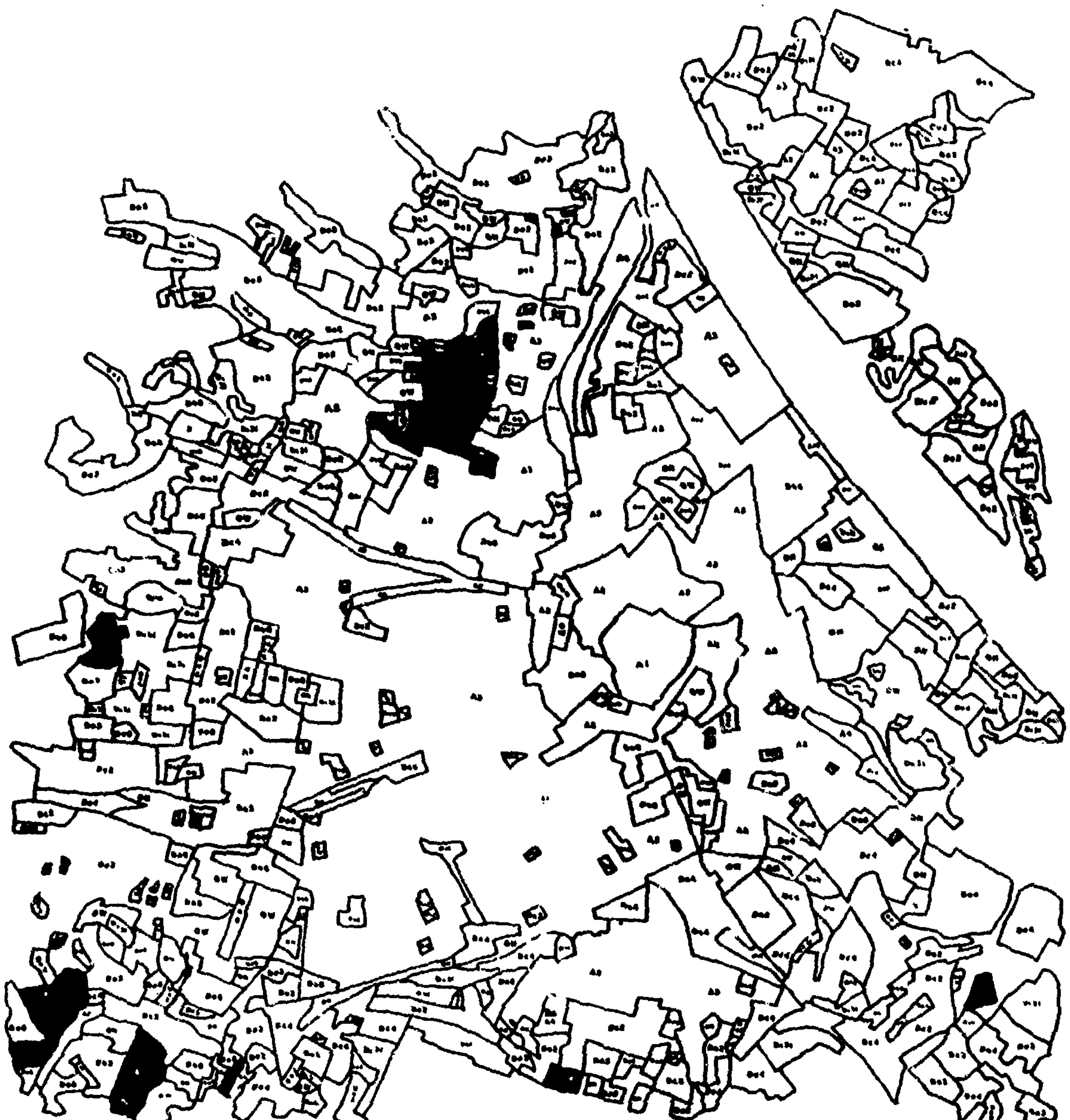
1:80,000 Vienna: Old Commercial Ribbons (A5)

1:80,000

Vienna: Apartments, >75% ground coverage (Dc2)

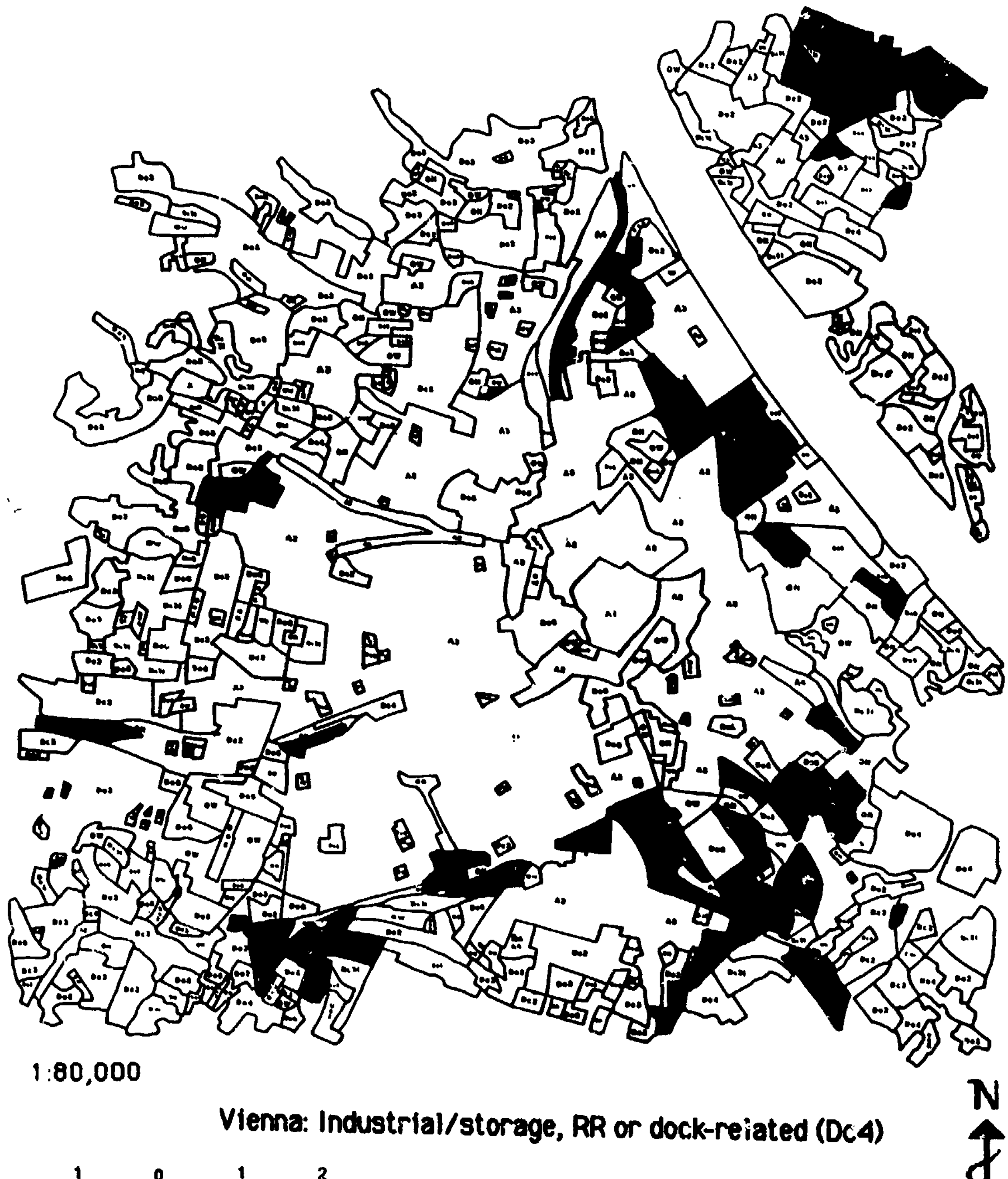
1 0 1 2
km

N

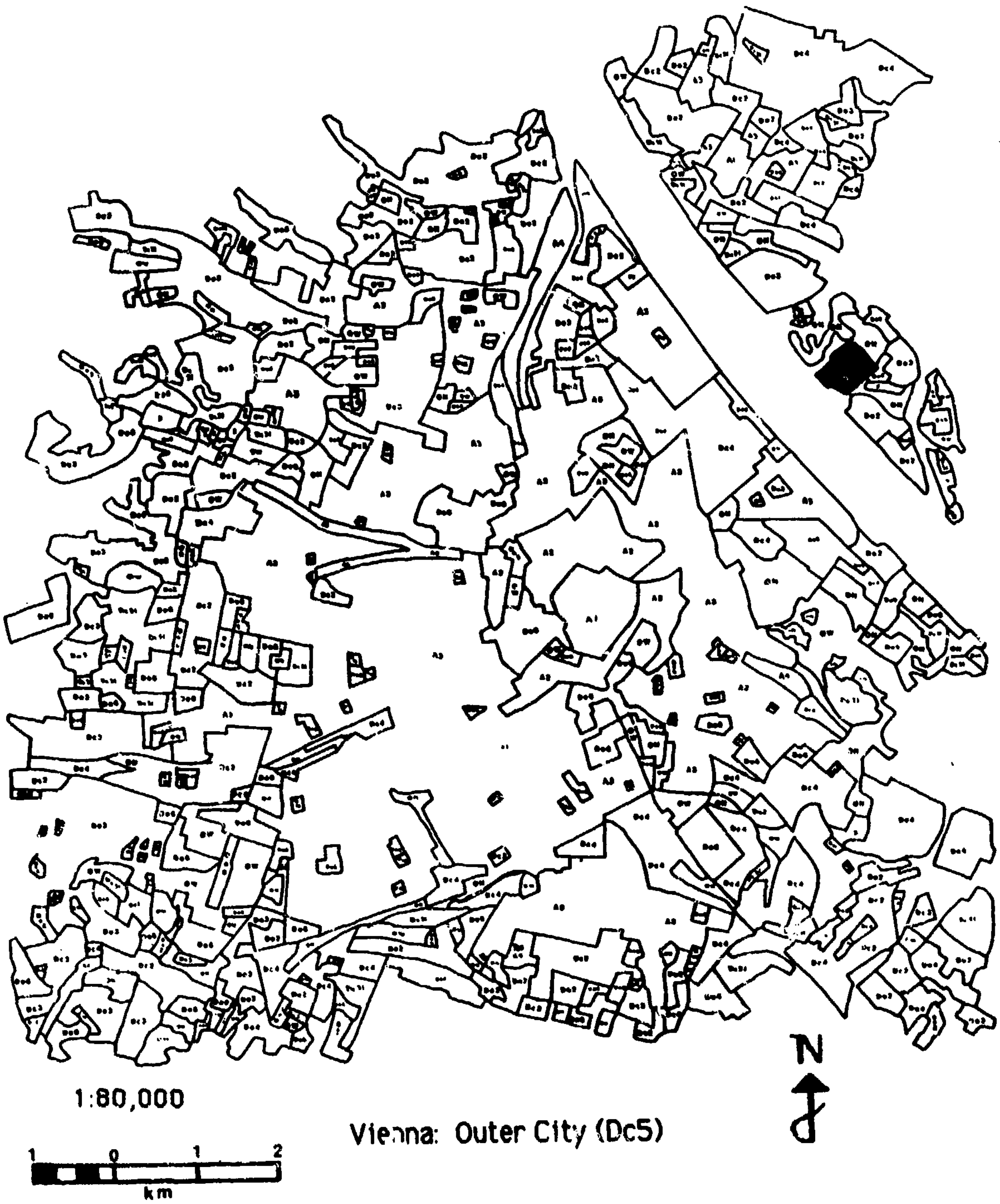


1:80,000

Vienna: Houses, >75% ground coverage (Dc3)



Vienna: Industrial/storage, RR or dock-related (Dc4)



Vienna: Outer City (Dc5)

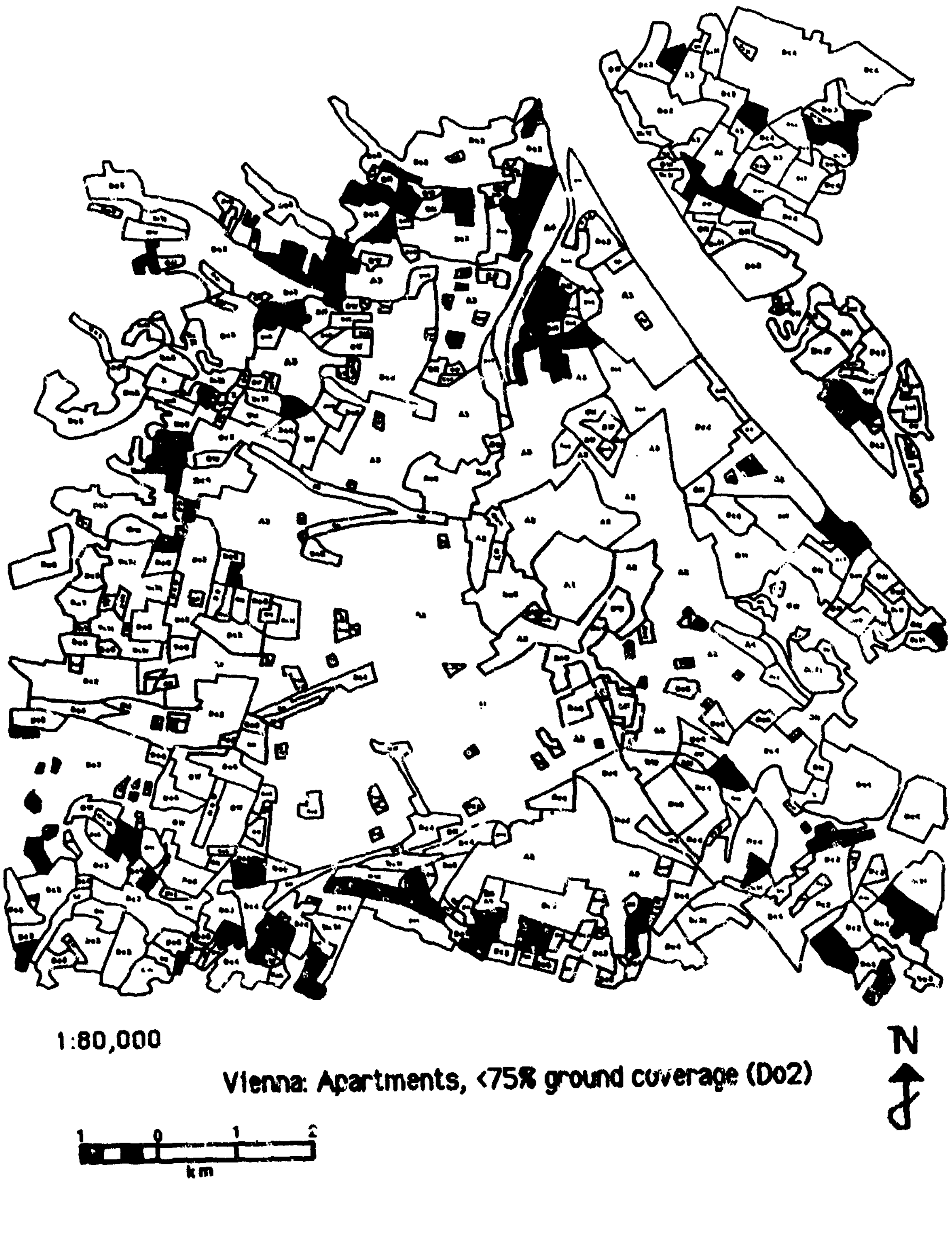
1:80,000

Vienna: Engulfed agricultural village (Dc7)

1 0 1 2

km

N



Vienna: Apartments, <75% ground coverage (Do2)

1:80,000

Vienna: Houses, <75% ground coverage (Do3)

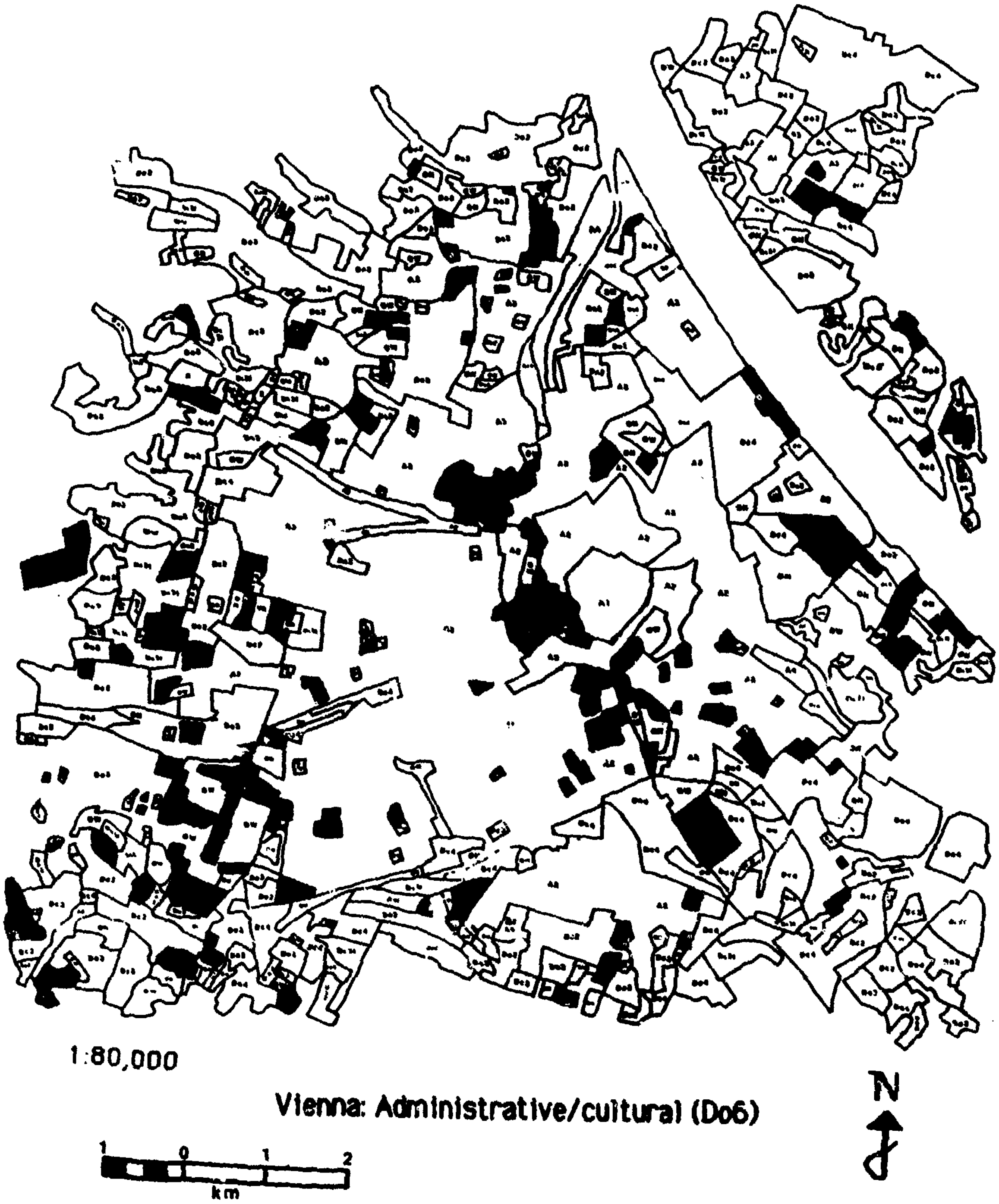
1:80,000

Vienna: Industrial/storage, truck-related (Do4)

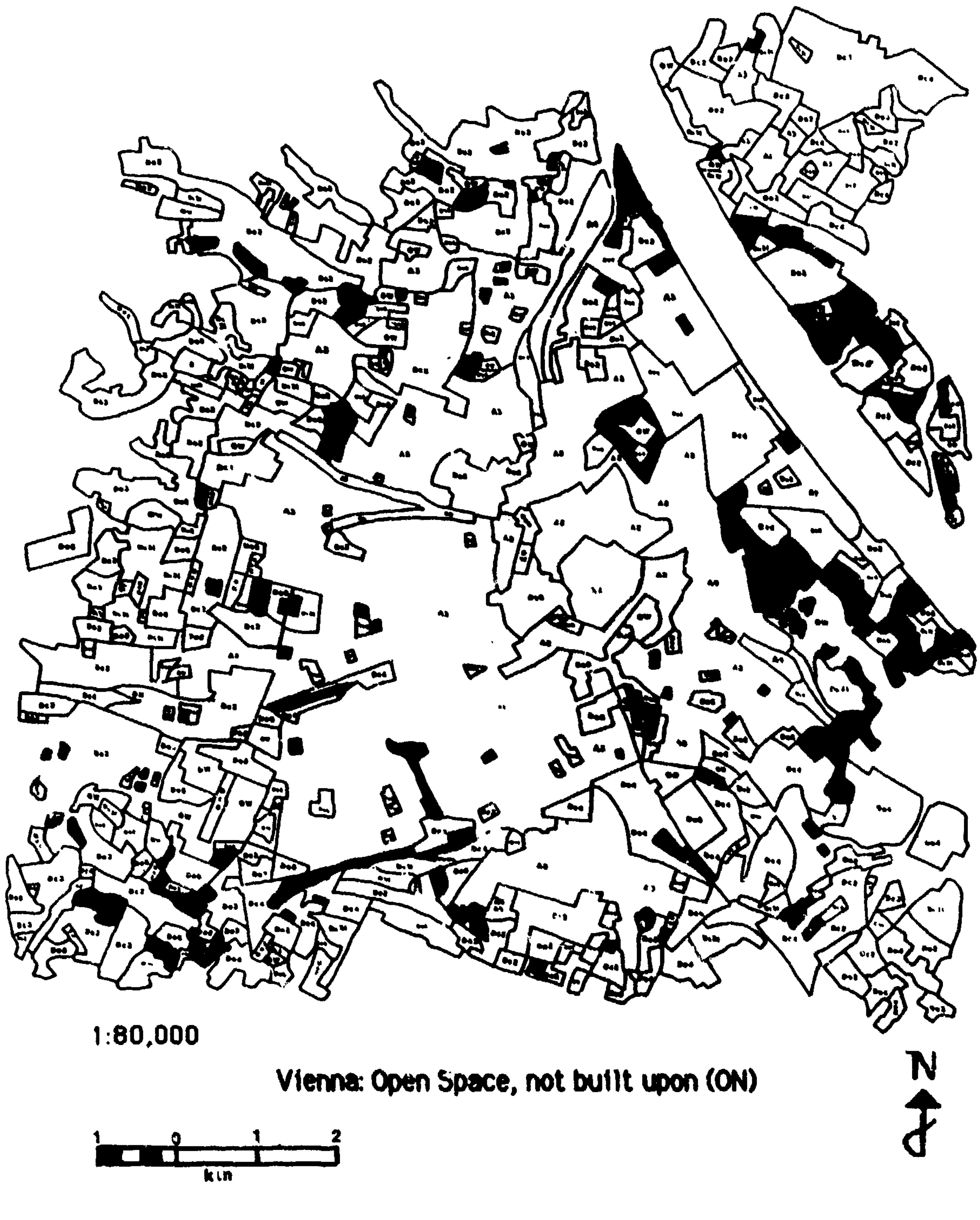
1 0 1 2

km

N



Vienna: Administrative/cultural (Do6)



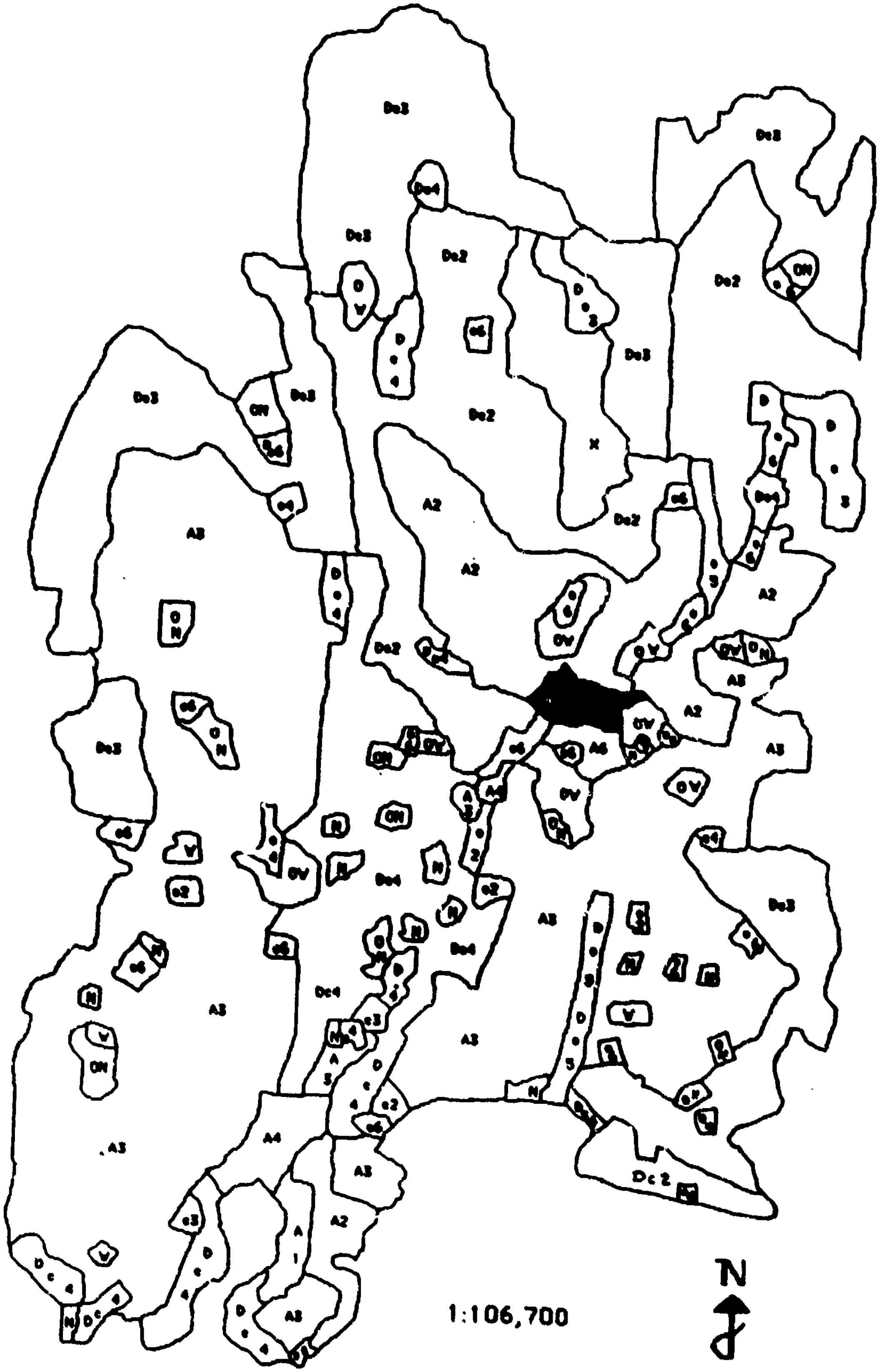
Vienna: Open Space, not built upon (ON)

1:80,000

Vienna: Open Space, wooded, not built upon (OW)

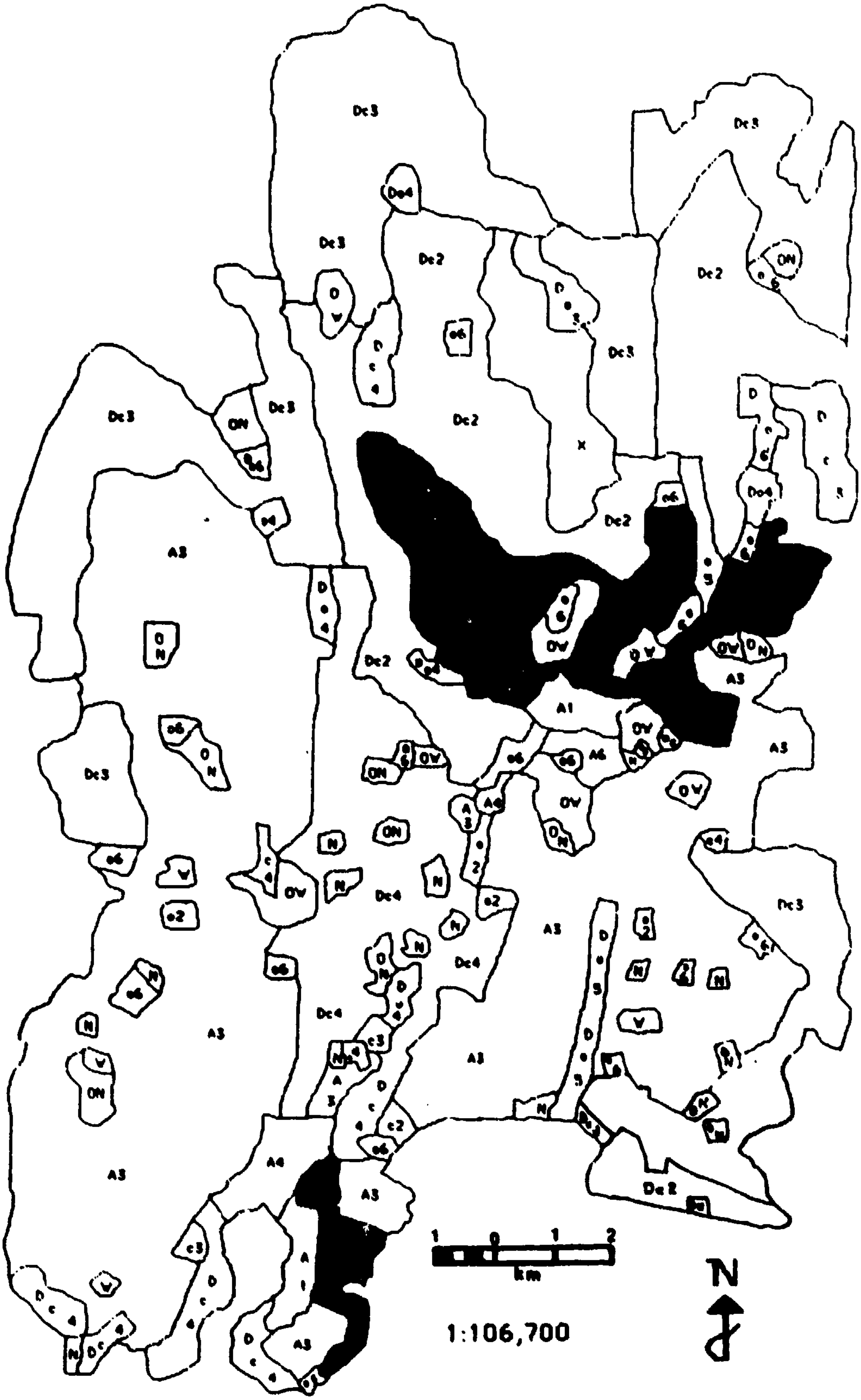
1:80,000

Vienna: Leased garden areas [with huts] (Do31)

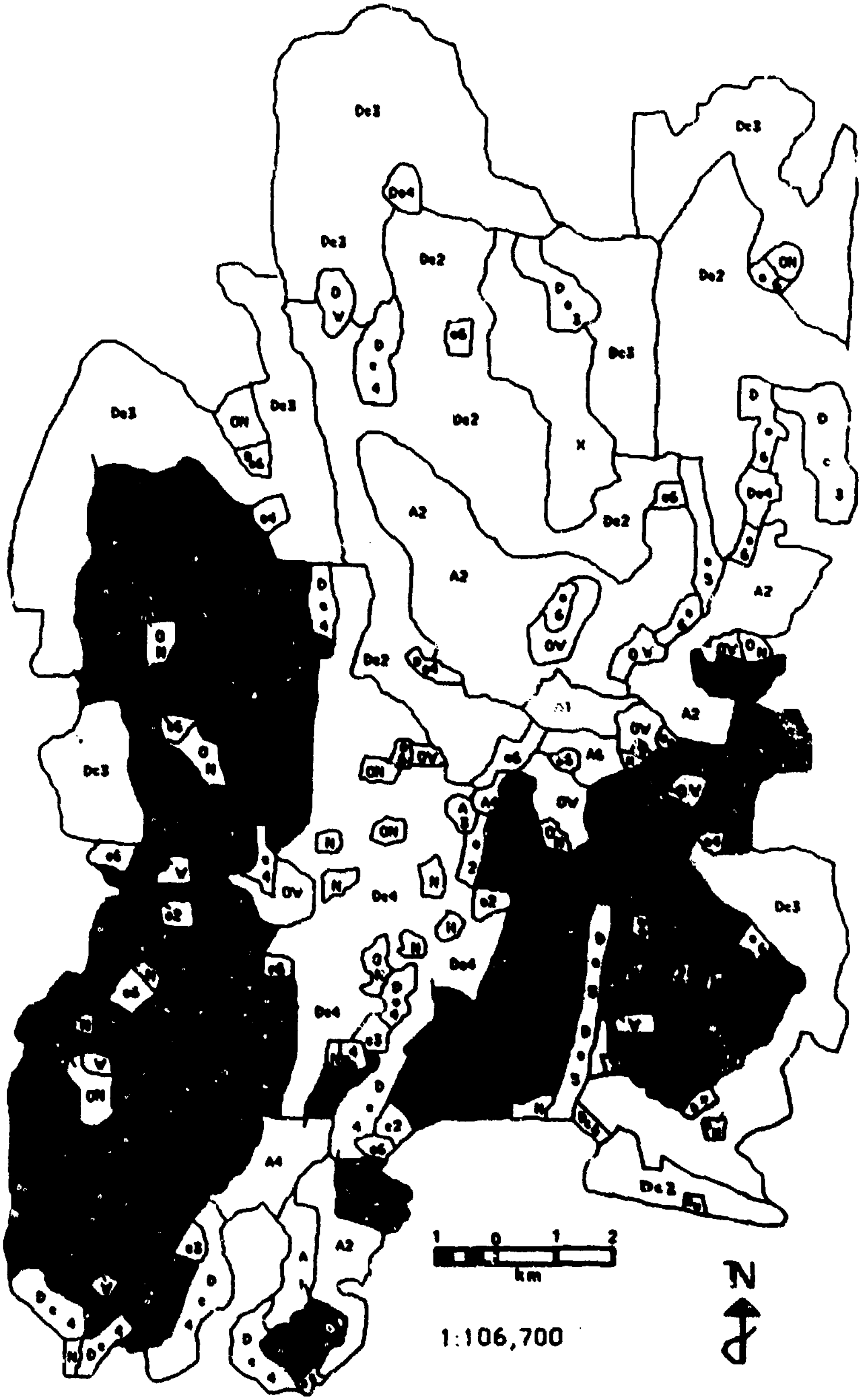


Athens-Piraeus: Core Area (A1)

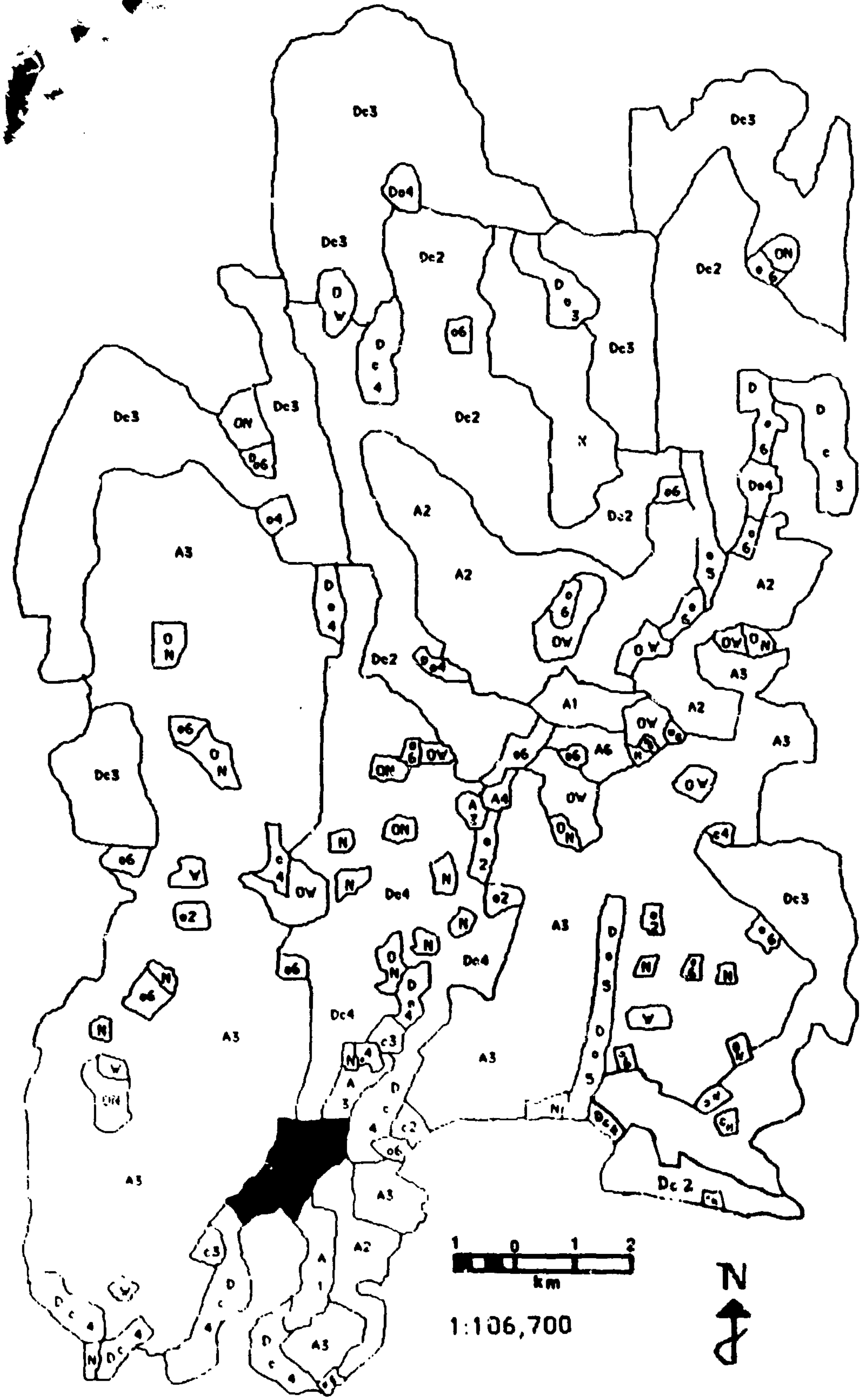
1 0 1 2
km



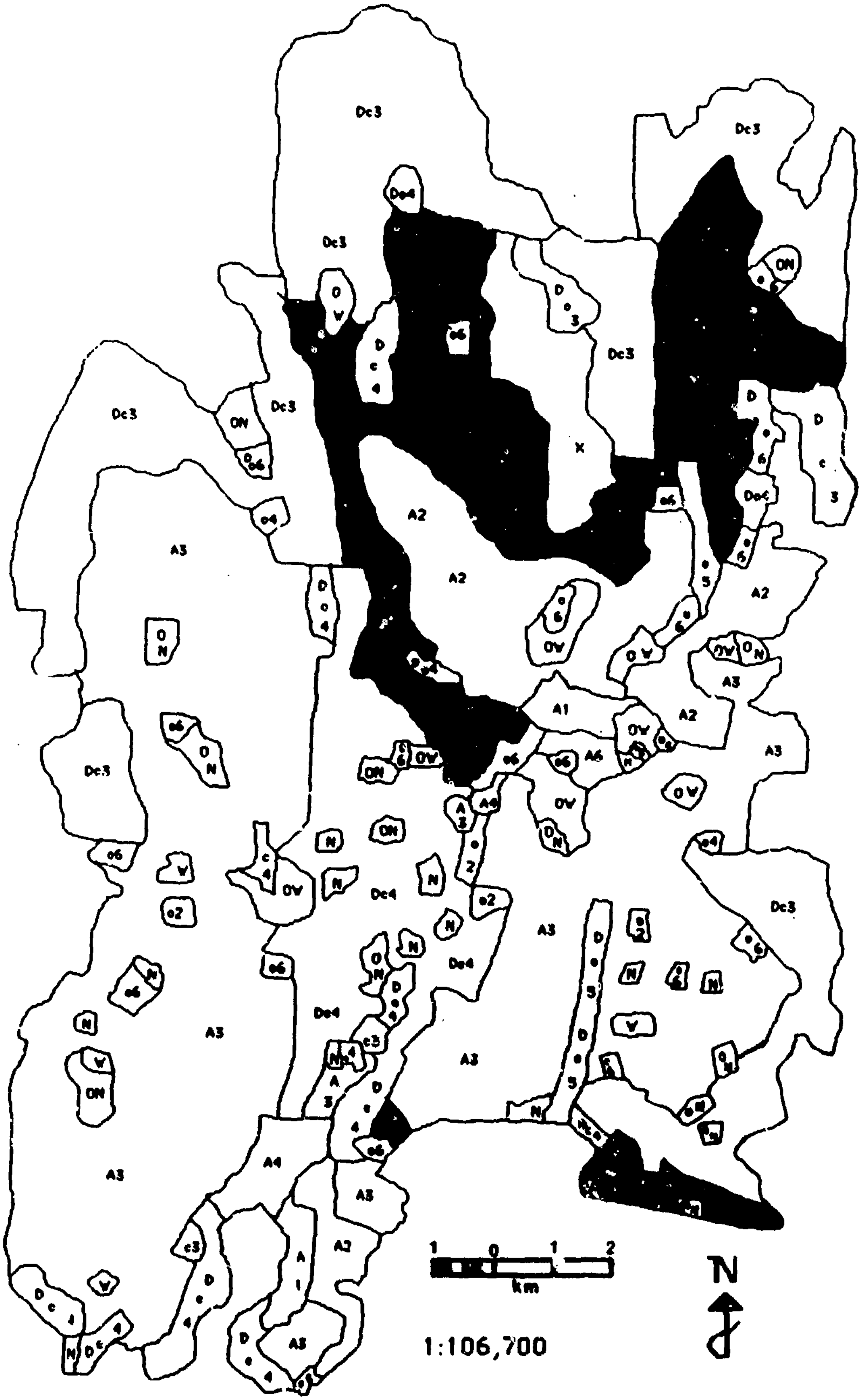
Athens-Piraeus: Apartments/hotels, core periphery (A2)



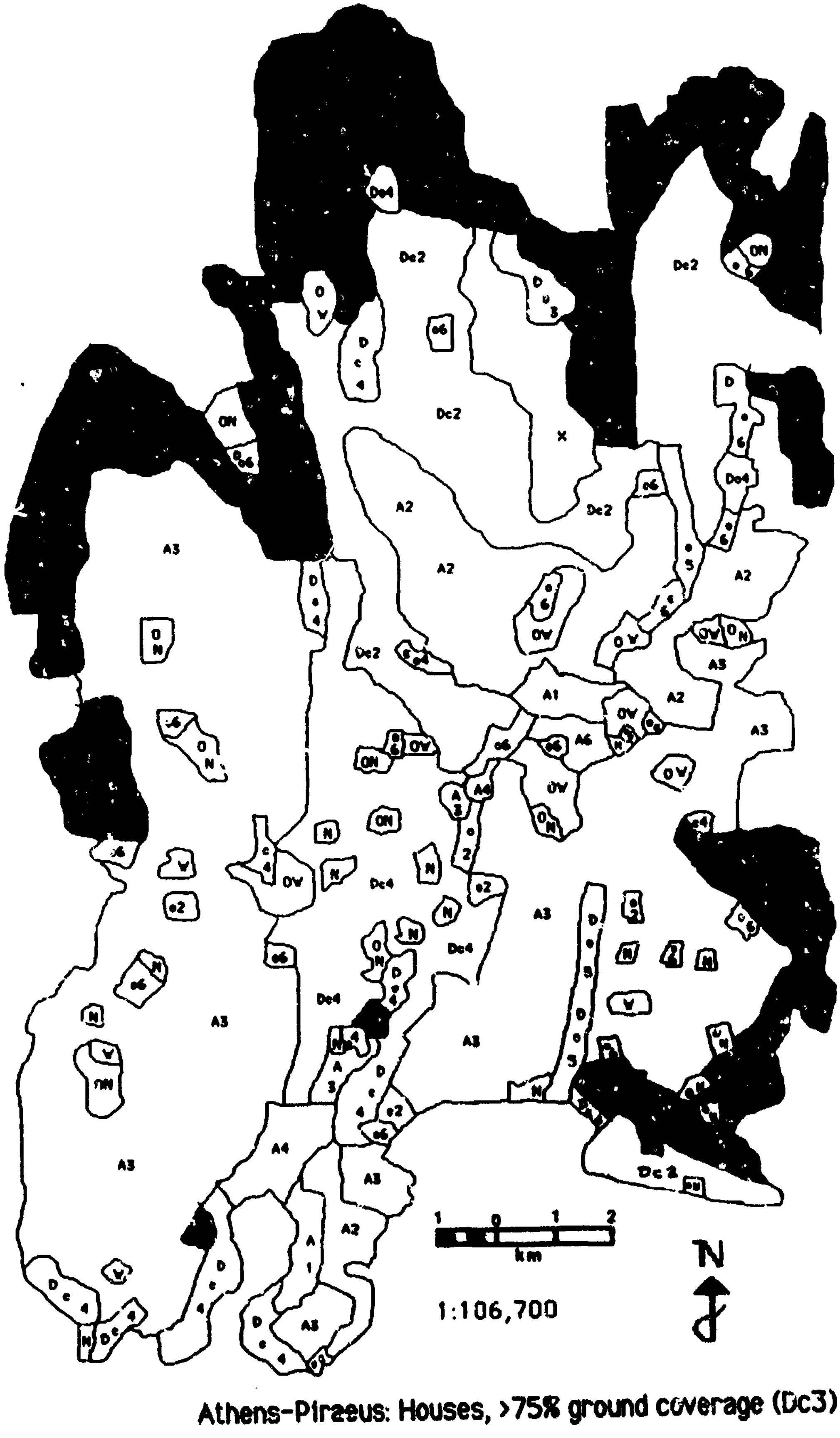
Athens-Piraeus: Apartments/row houses (A3)



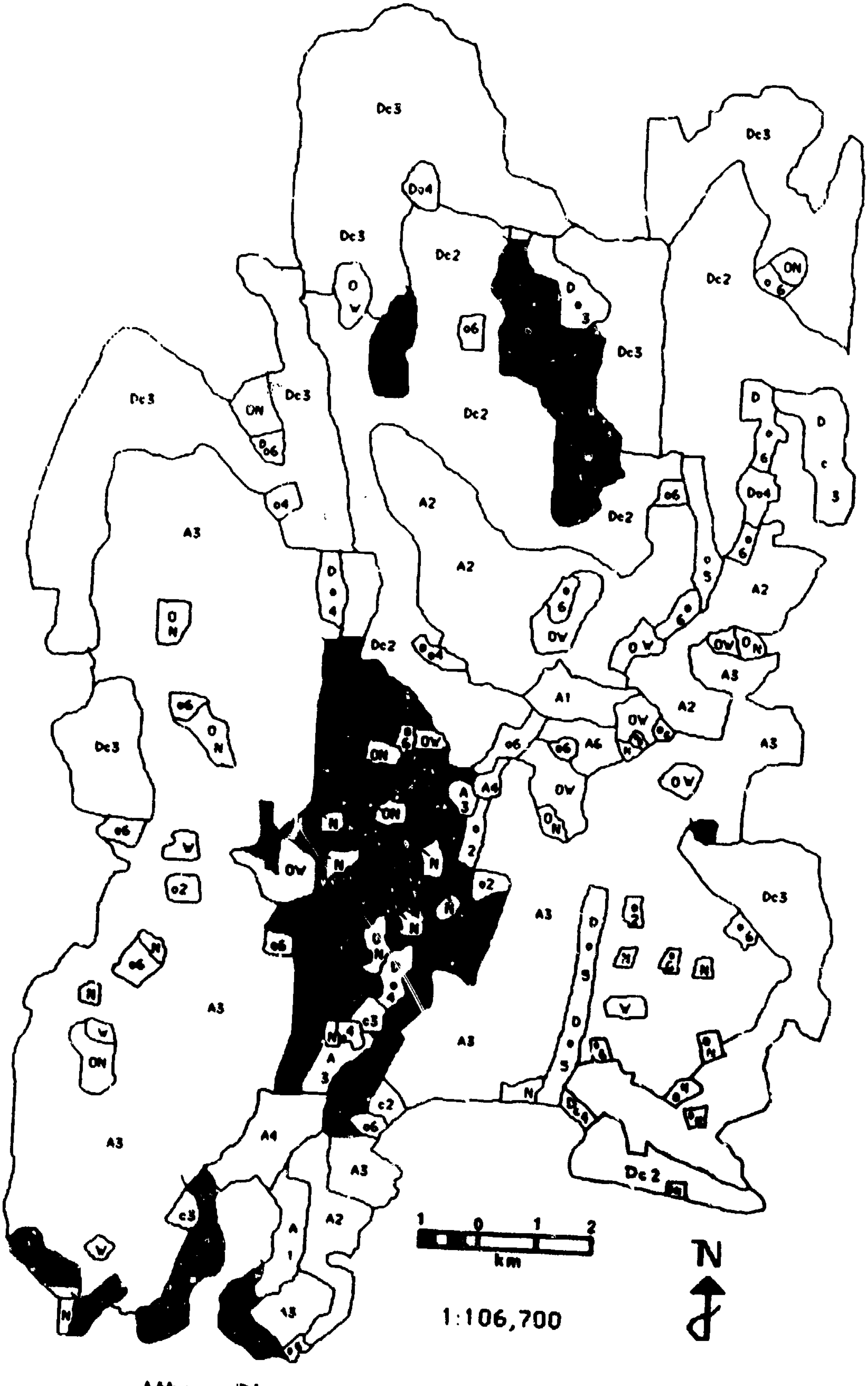
Athens-Piraeus: Industrial/storage, full urban form (A4)



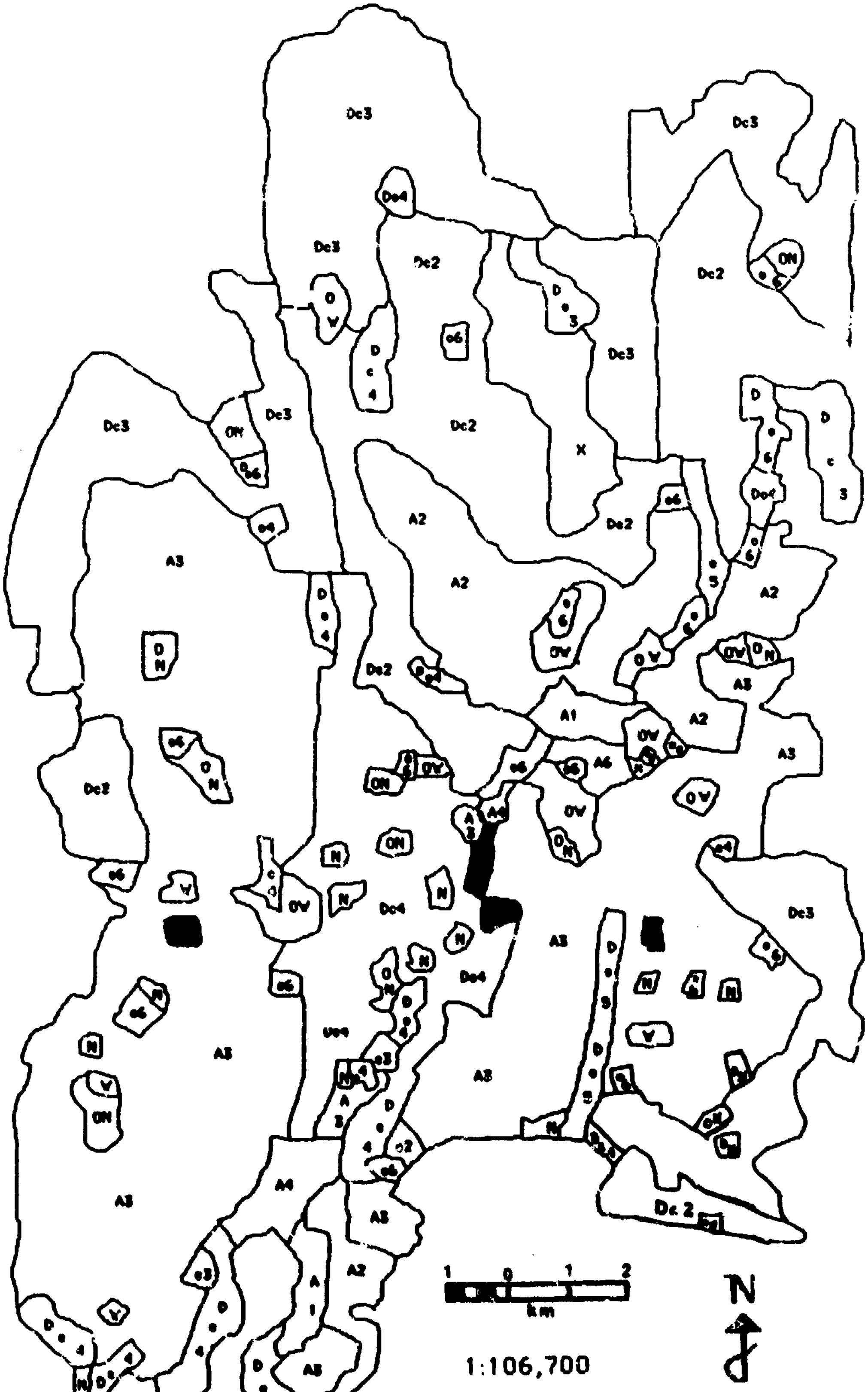
Athens-Piraeus: Apartments, >75% ground coverage (Dc2)



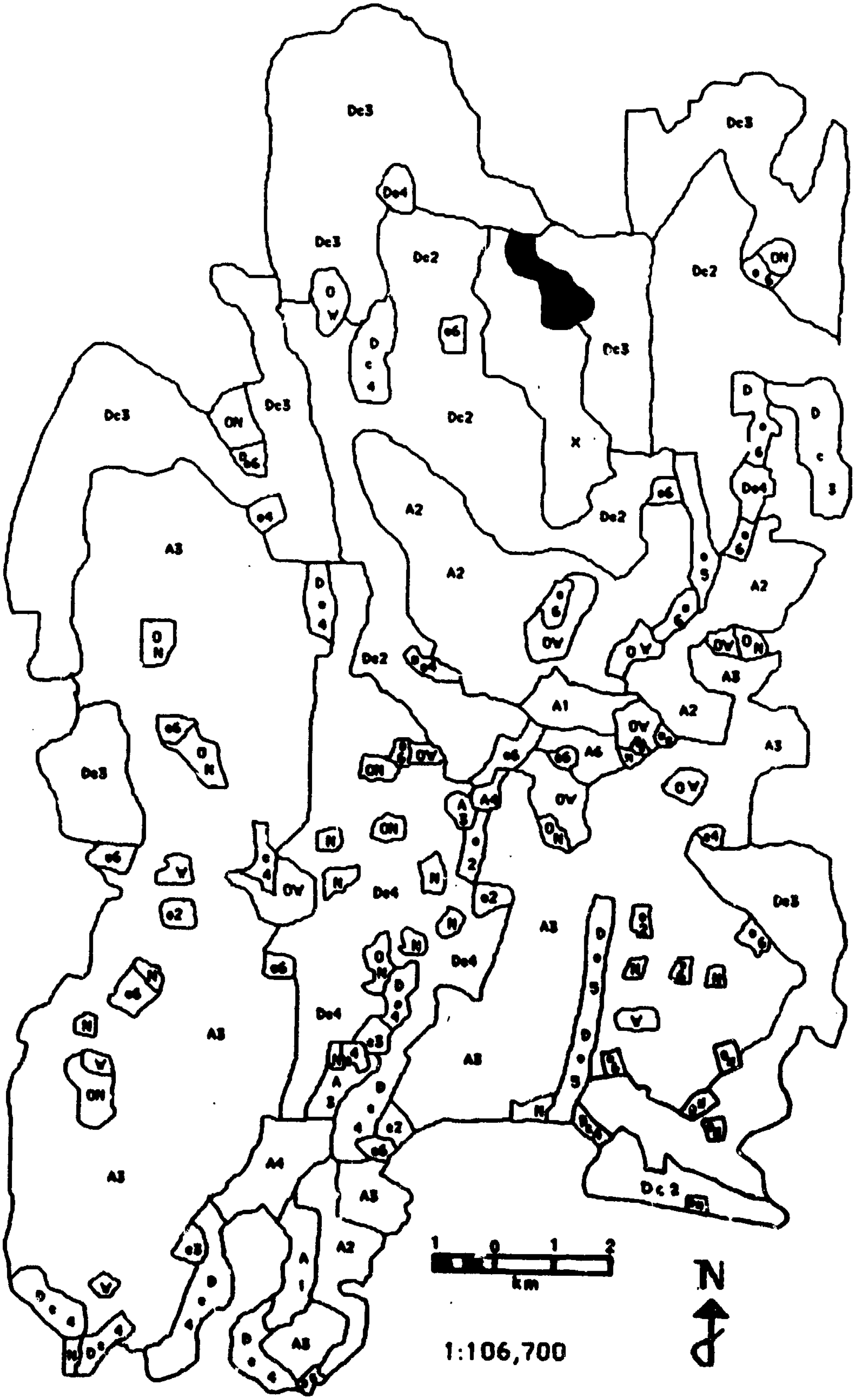
Athens-Piraeus: Houses, >75% ground coverage (Dc3)



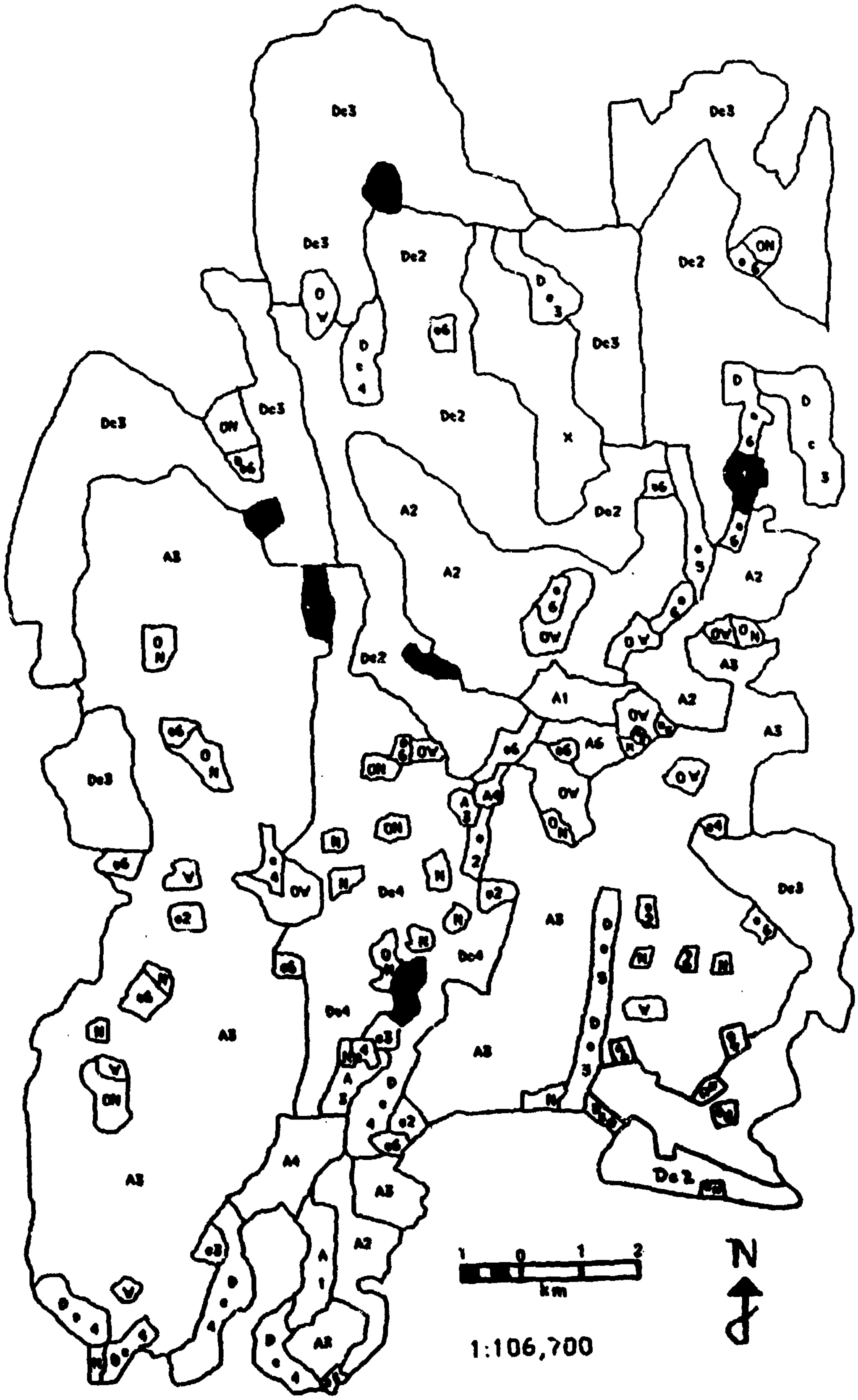
Athens-Piraeus: Industrial/storage, RR or dock-related (Dc4)



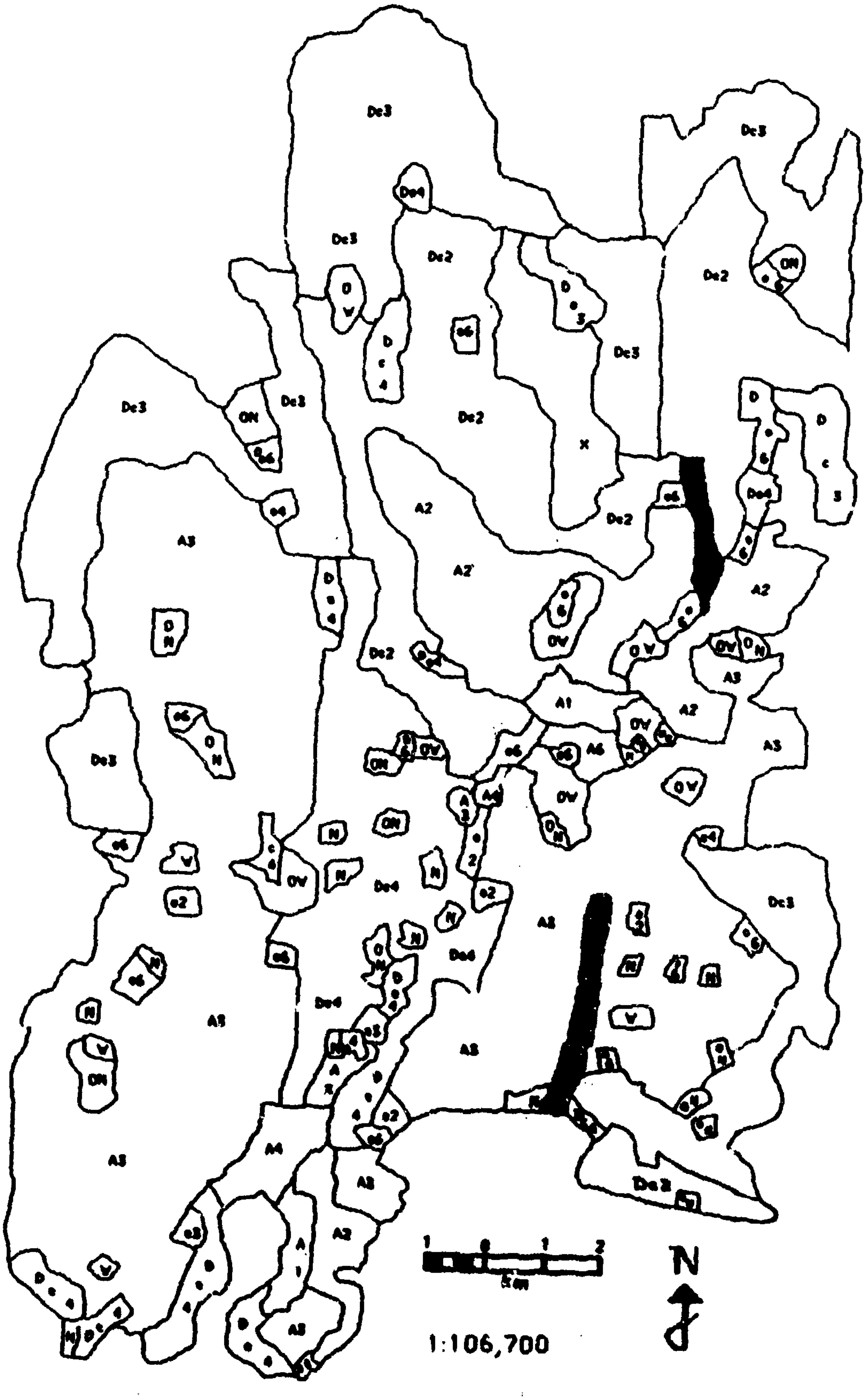
Athens-Piraeus: Apartments, <75% ground coverage (Do2)



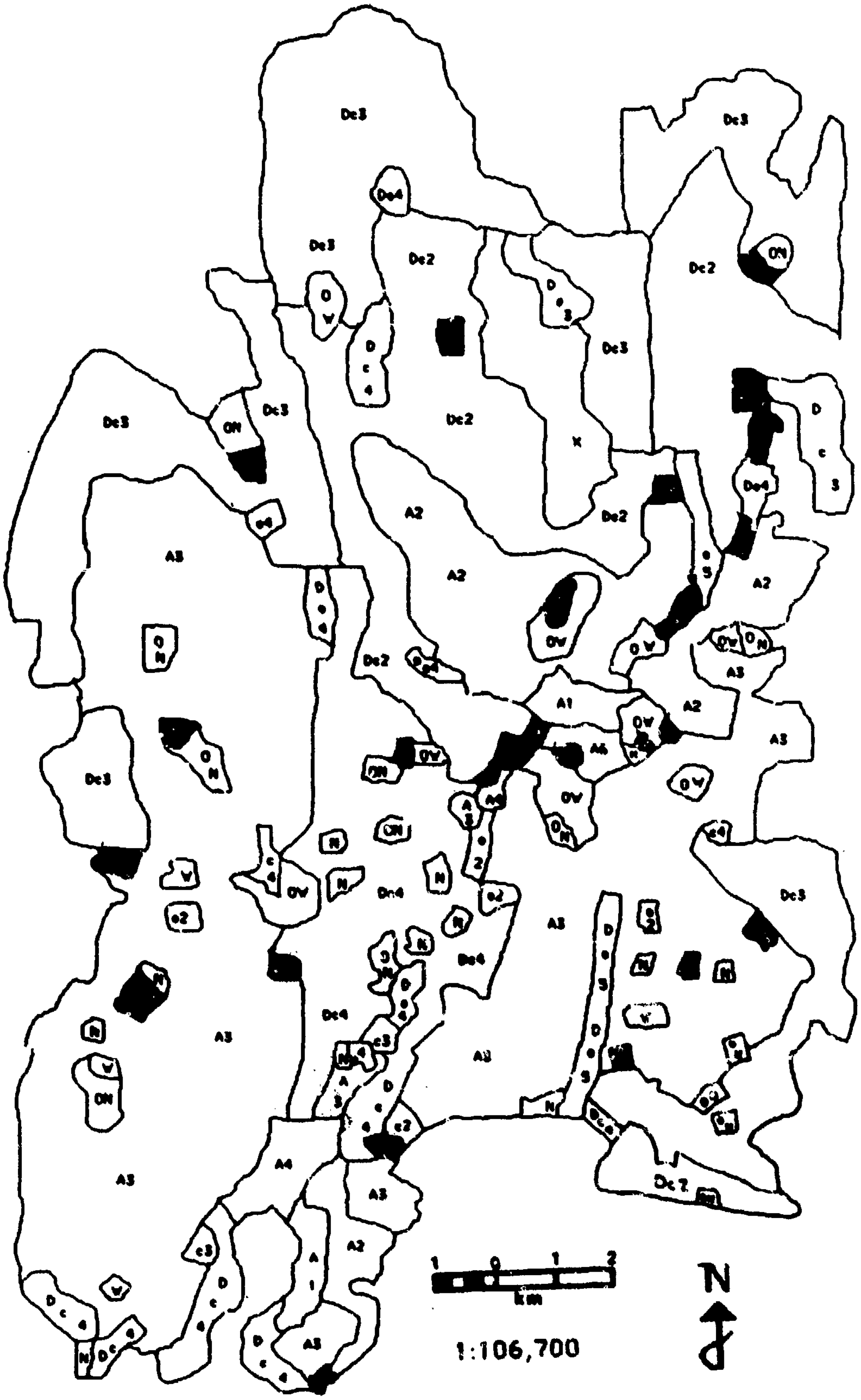
Athens-Piraeus: Houses, <75% ground coverage (Do3)



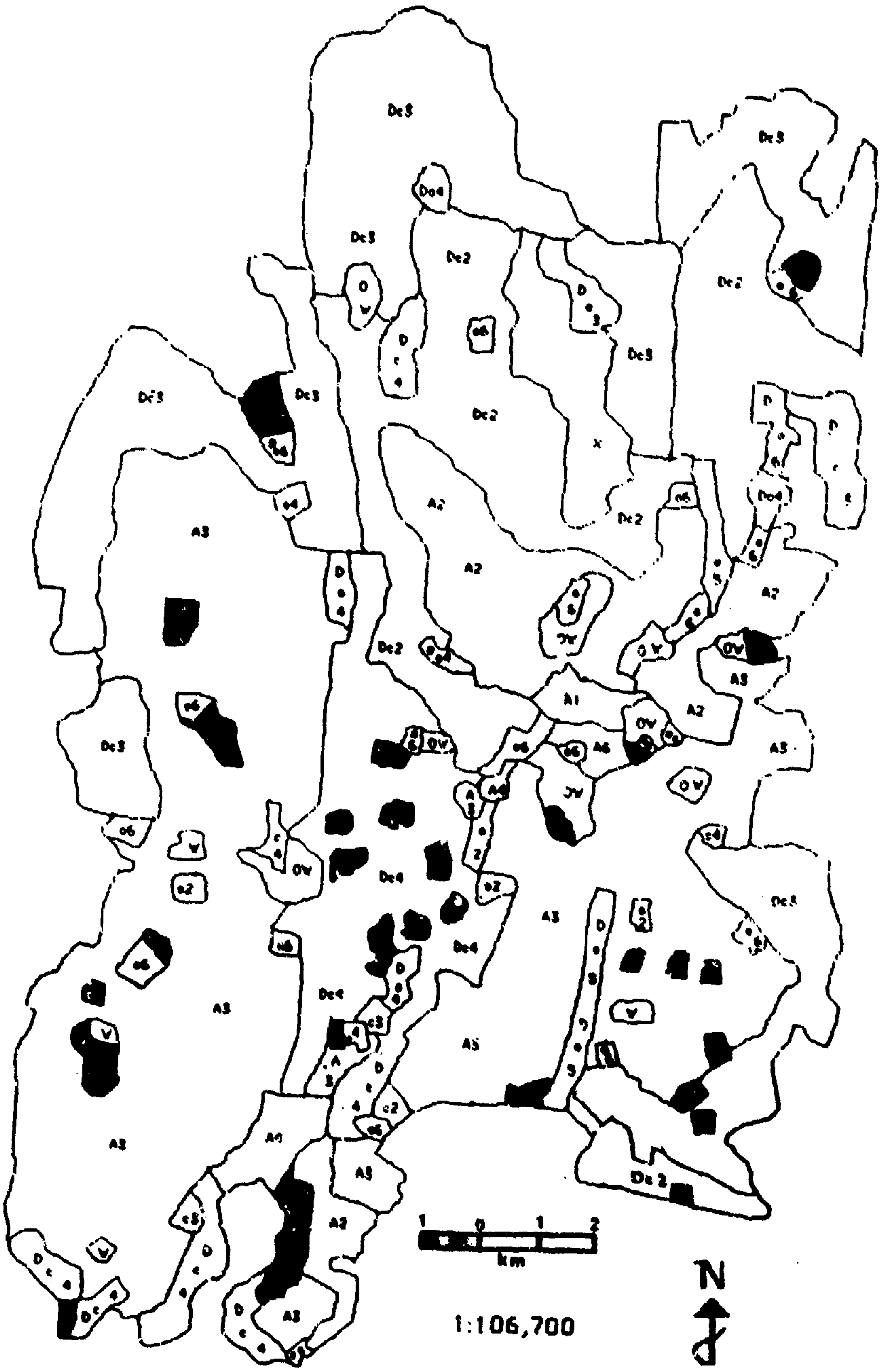
Athens-Piraeus: Industrial/storage, truck-related (Do4)



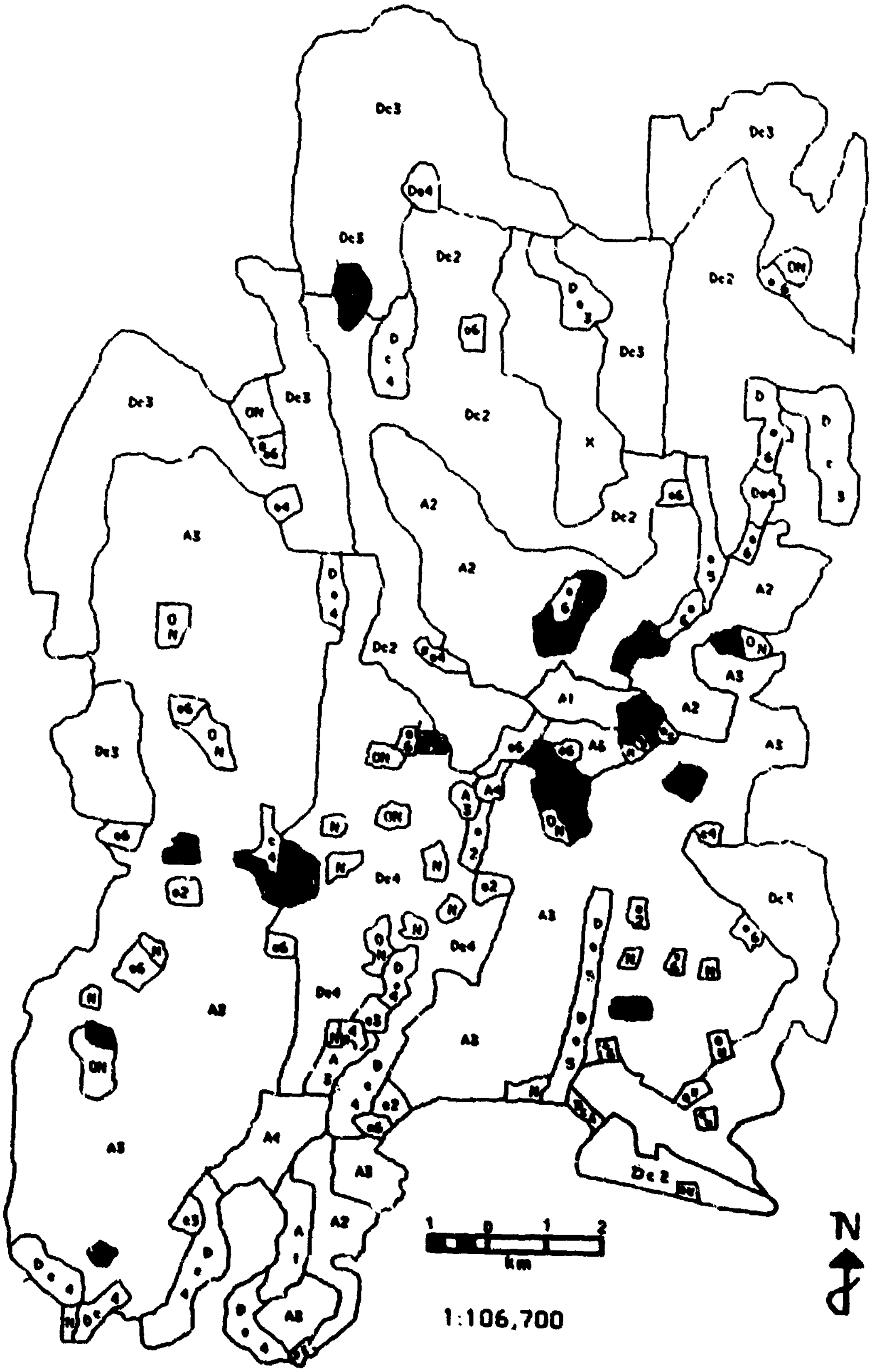
Athens-Piraeus: New Commercial Ribbons (Do5)



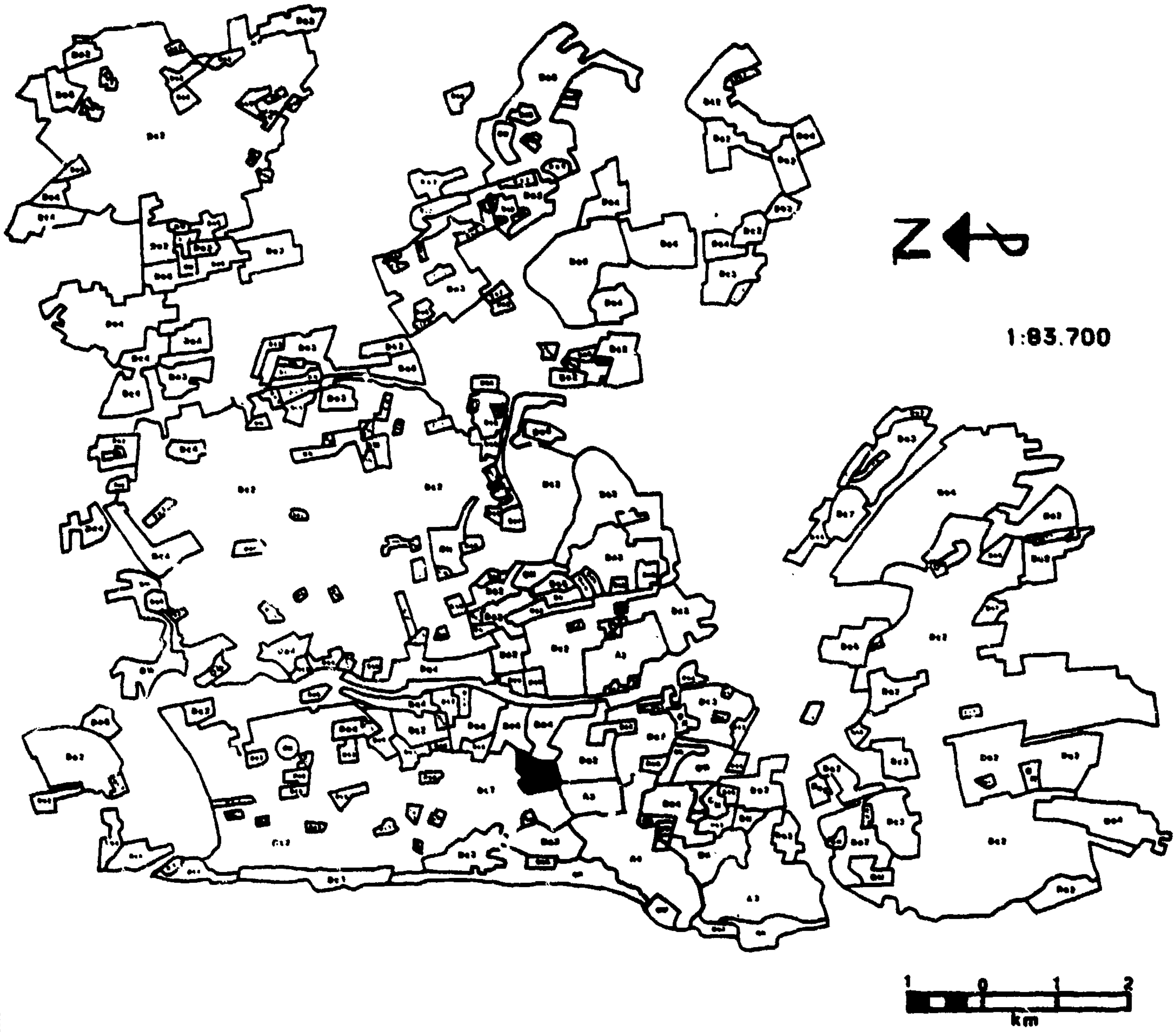
Athens-Piraeus: Administrative/cultural (Do6)



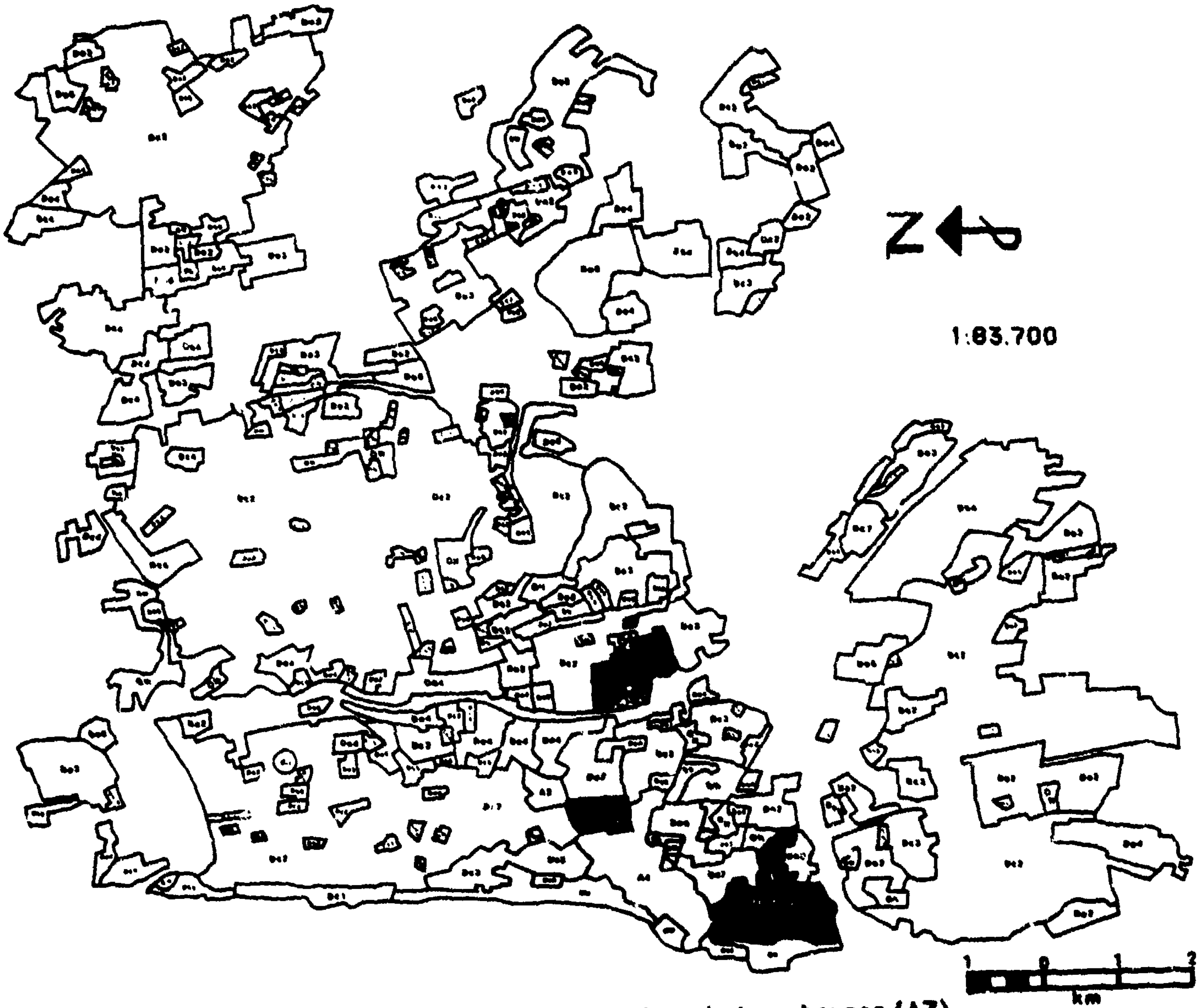
Athens-Piraeus: Open Space, not built upon (ON)



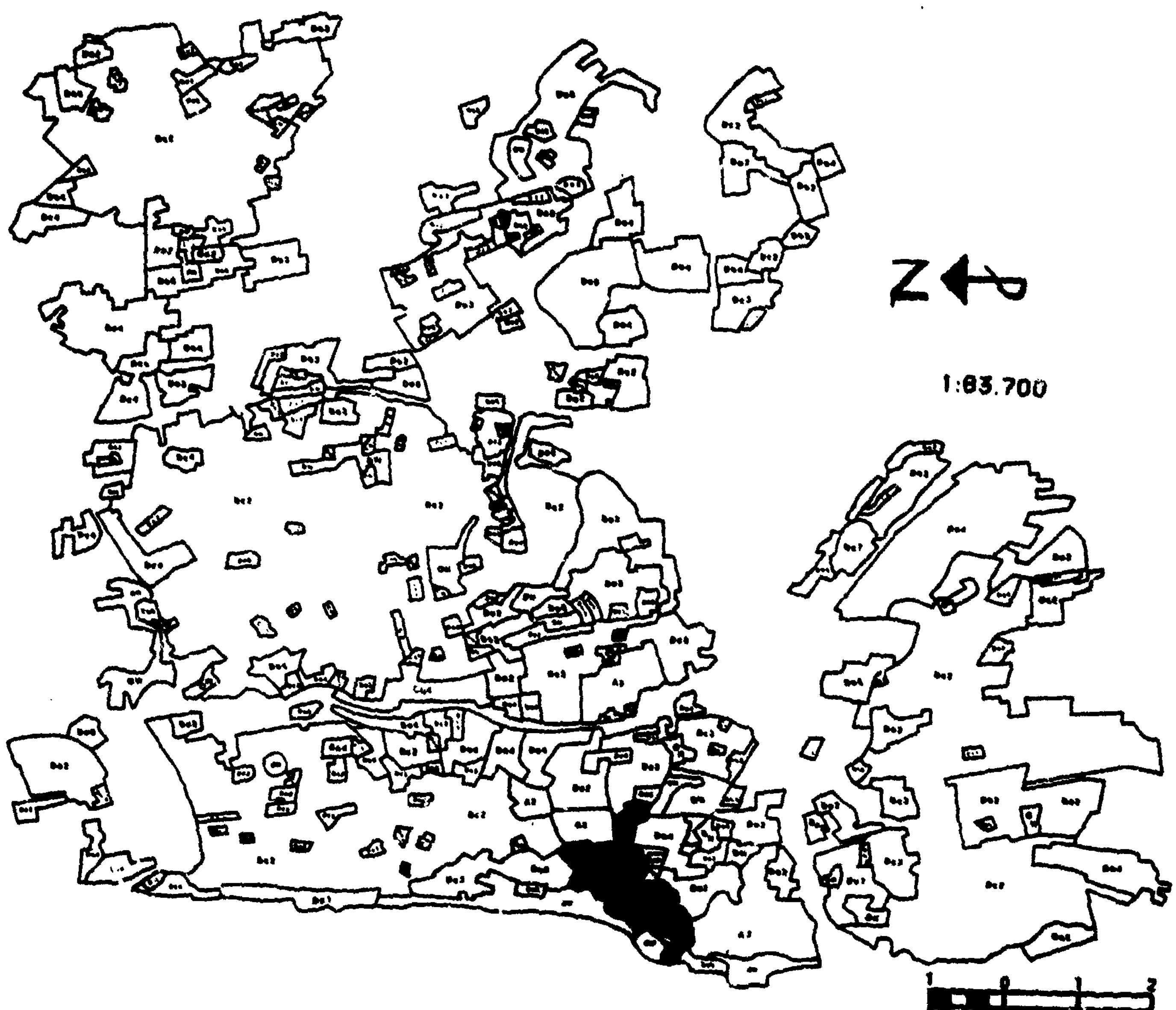
Athens-Piraeus: Open Space, wooded, not built upon (OW)



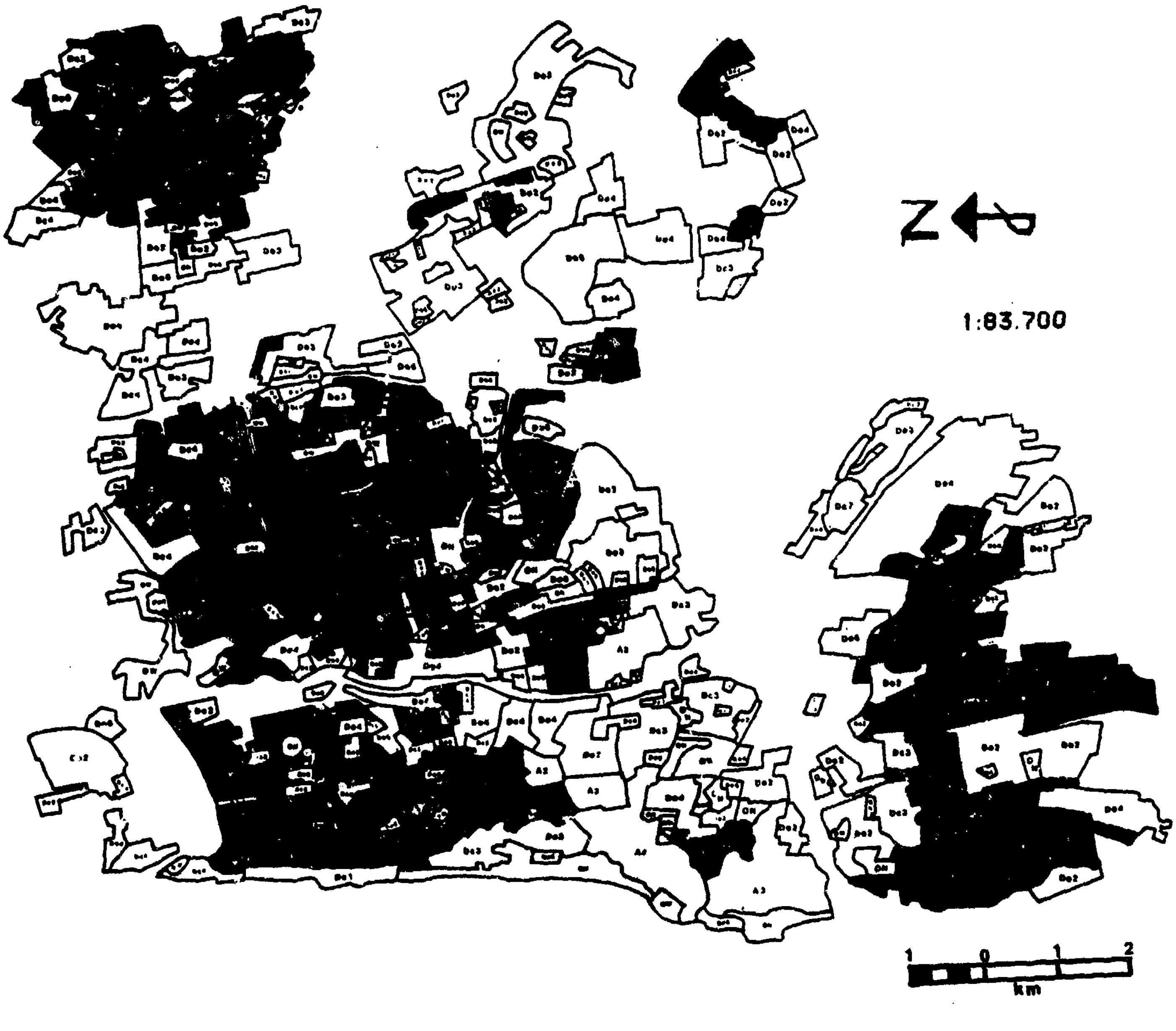
Tel Aviv-Yafo: Apartments/hotels, core periphery (A2)



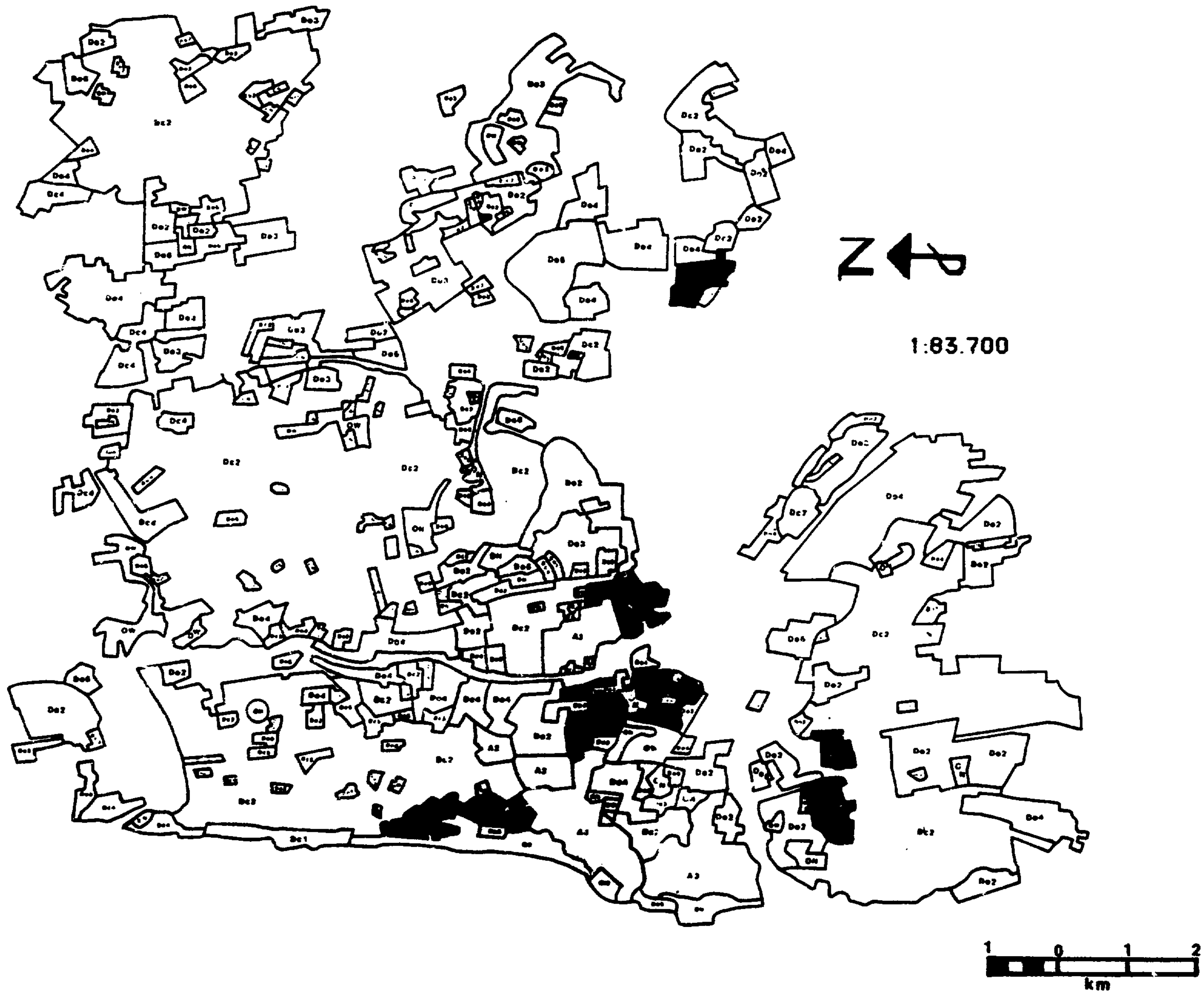
Tel Aviv-Yafo: Apartments/row houses (A3)



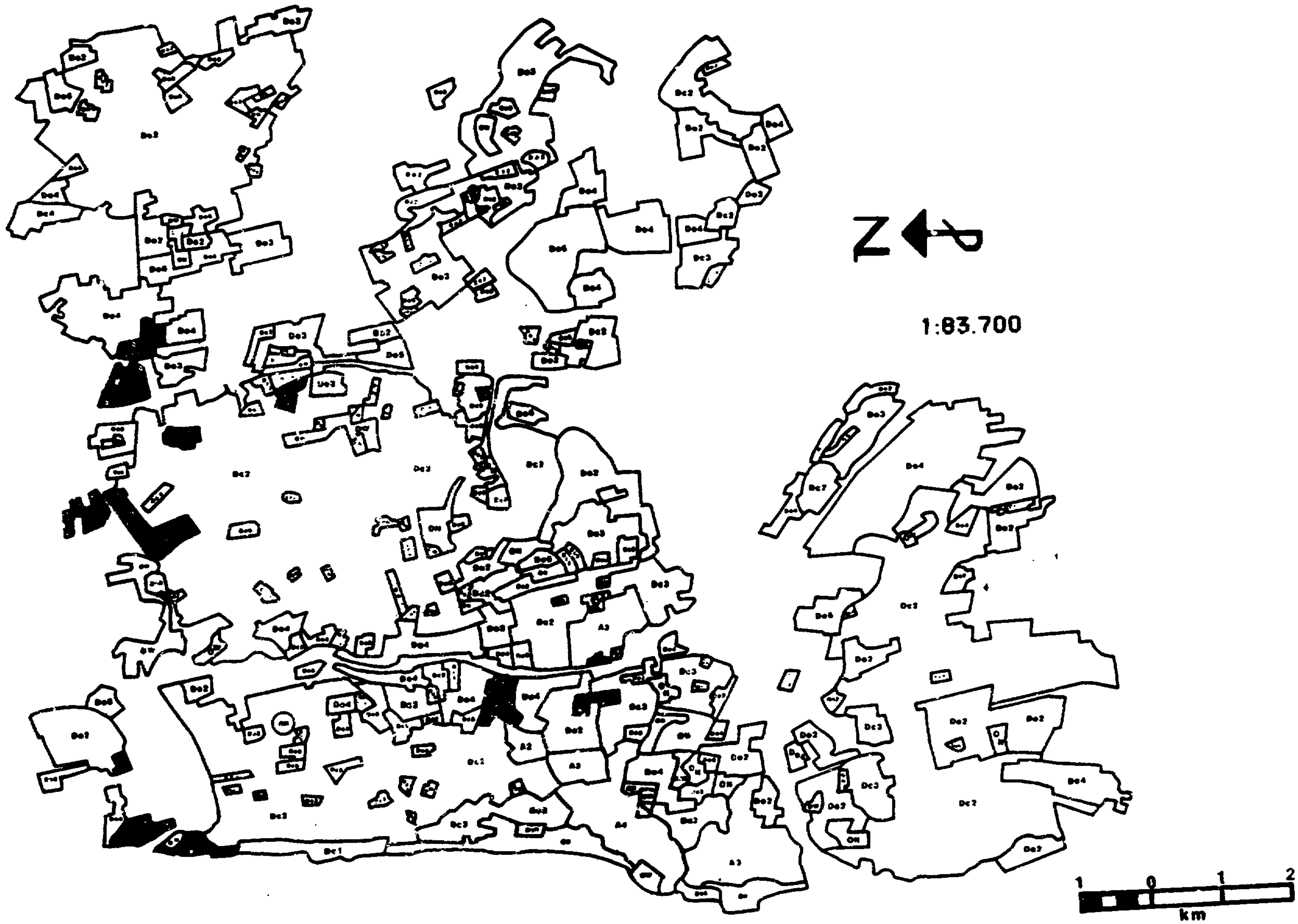
Tel Aviv-Yafo: industrial/storage, full urban form (A4)



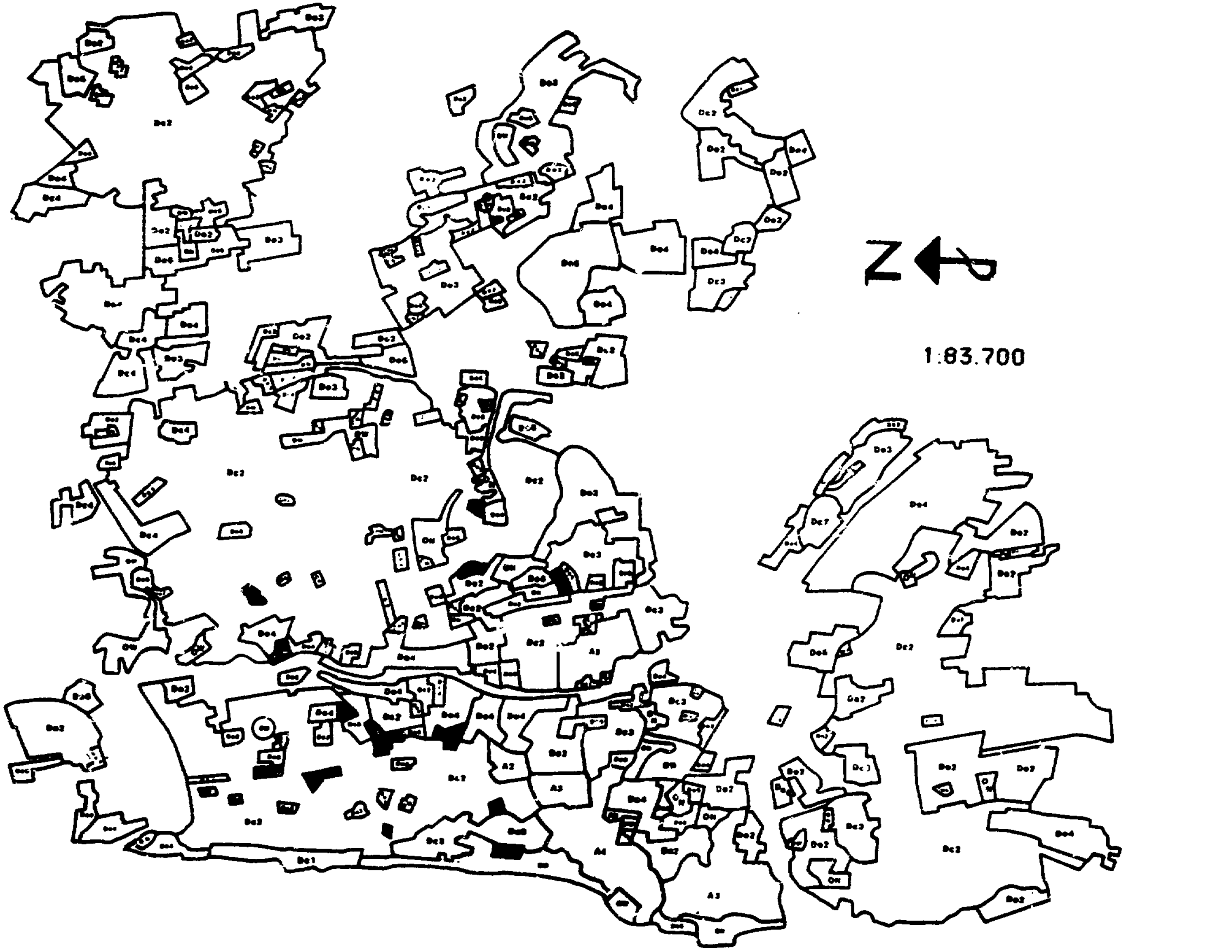
Tel Aviv-Yafo: Apartments, >75% ground coverage (Dc2)



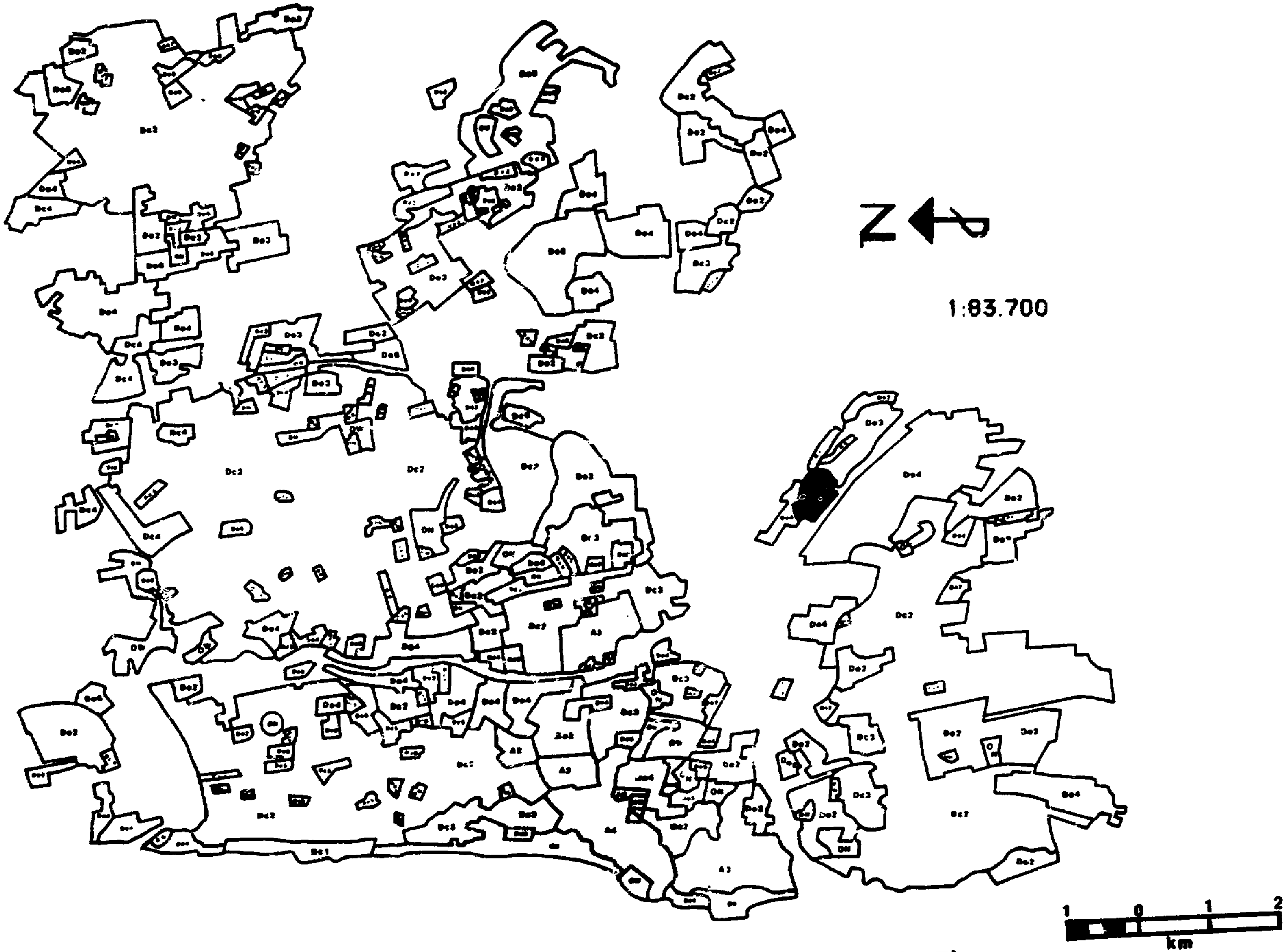
Tel Aviv-Yafo: Houses, >75% ground coverage (Dc3)



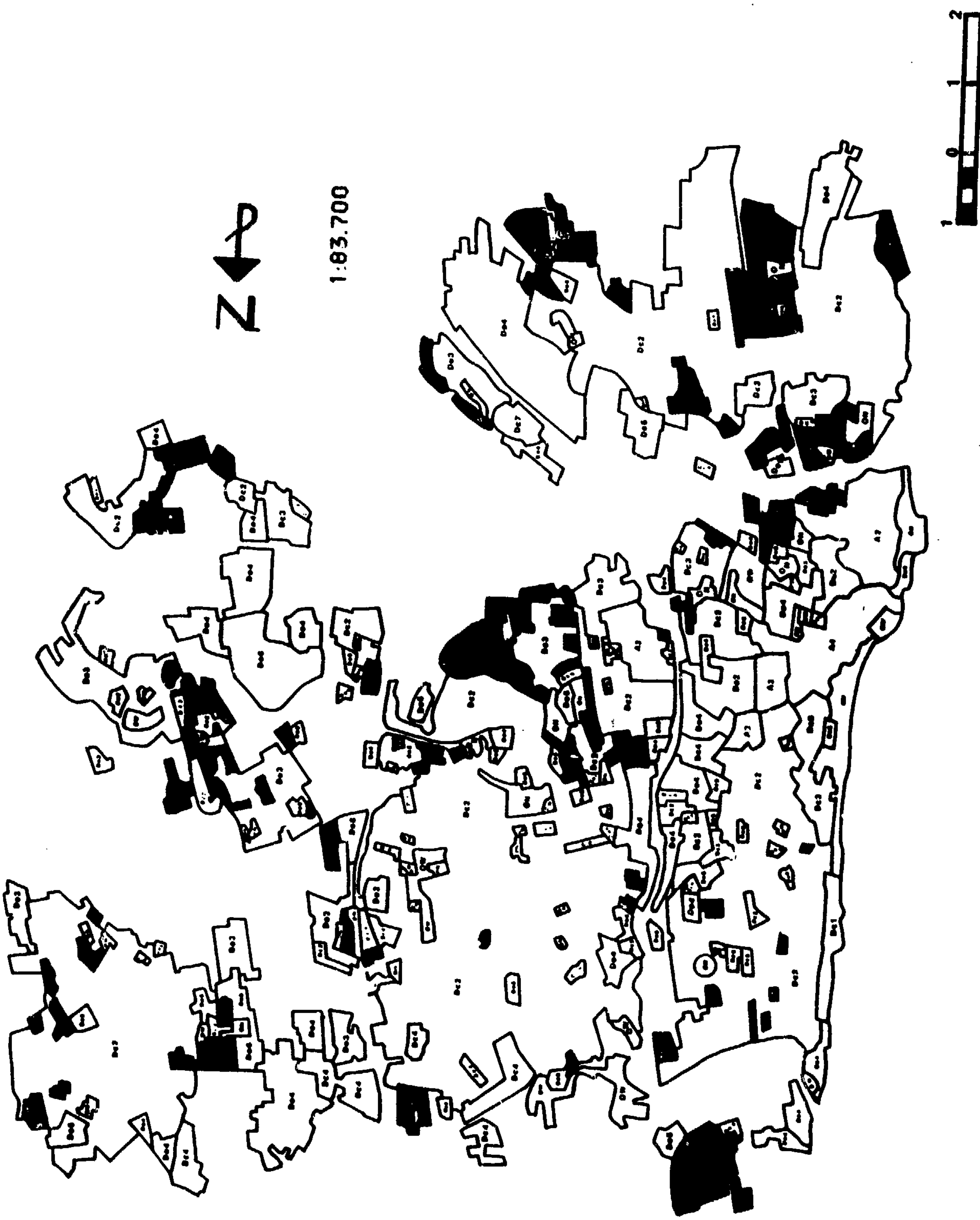
Tel Aviv-Yafo: Industrial/storage, RR or dock-related (Dc4)



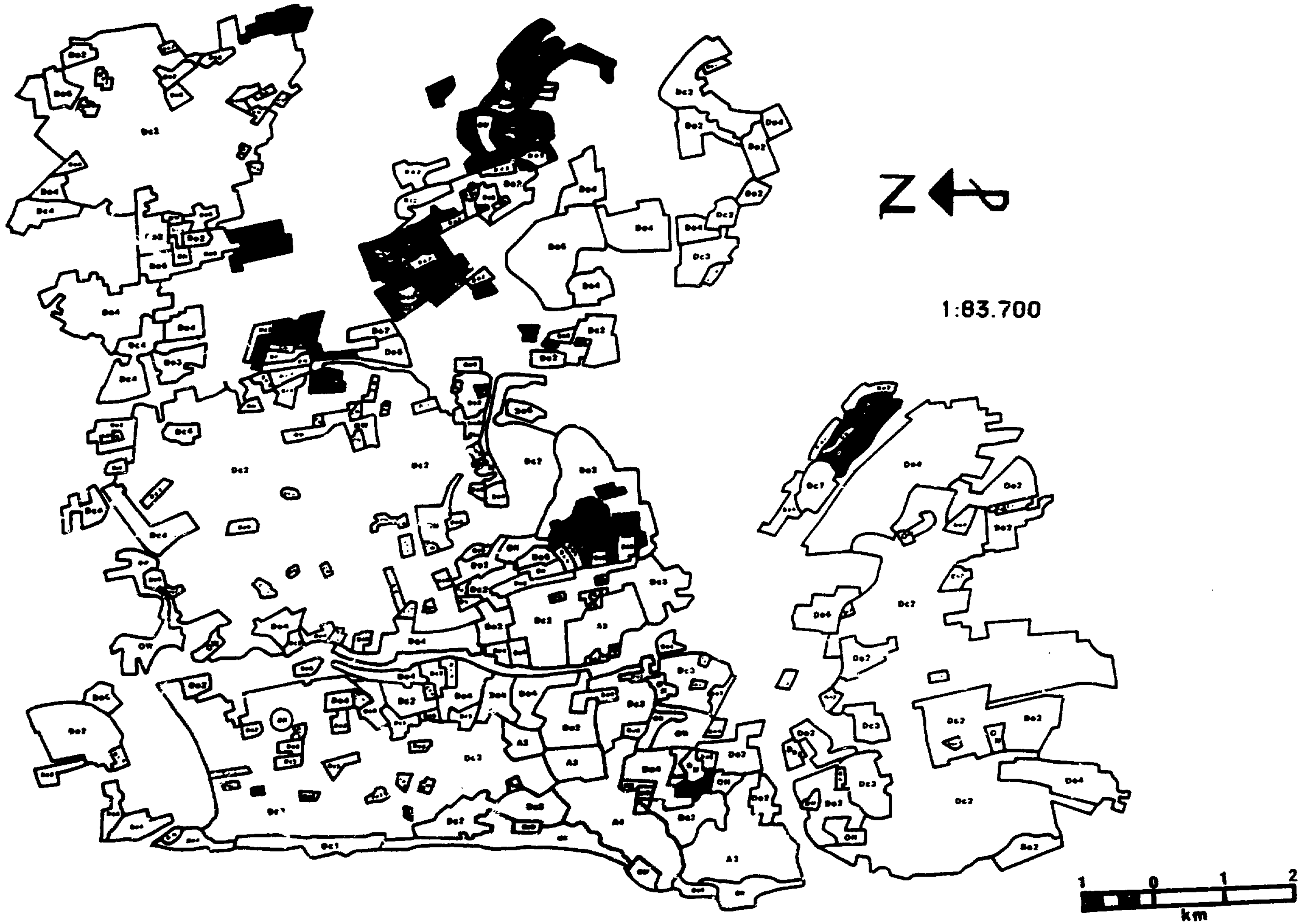
Tel Aviv-Yafo: Outer City (Dc5)



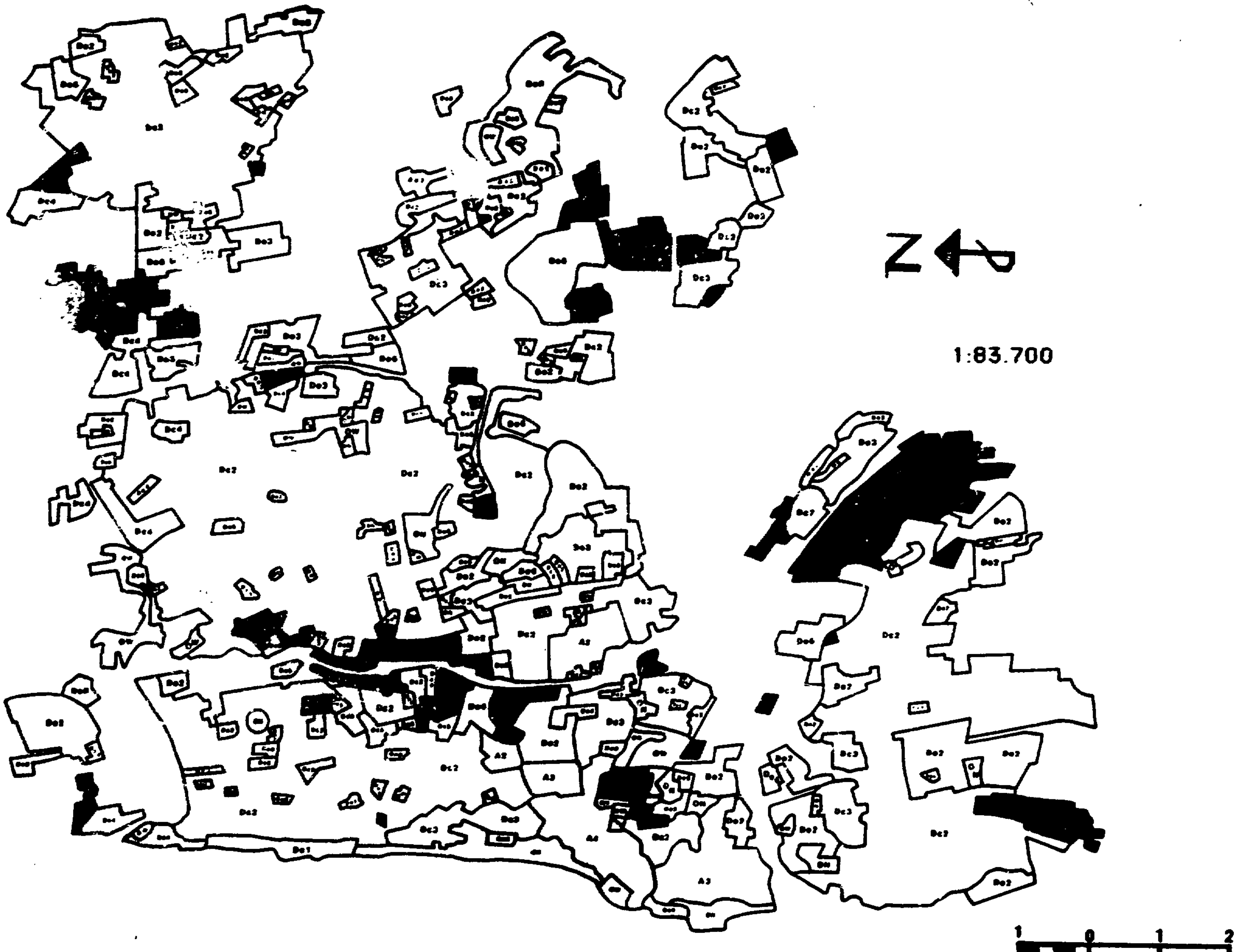
Tel Aviv-Yafo: Engulfed agricultural village (Dc7)



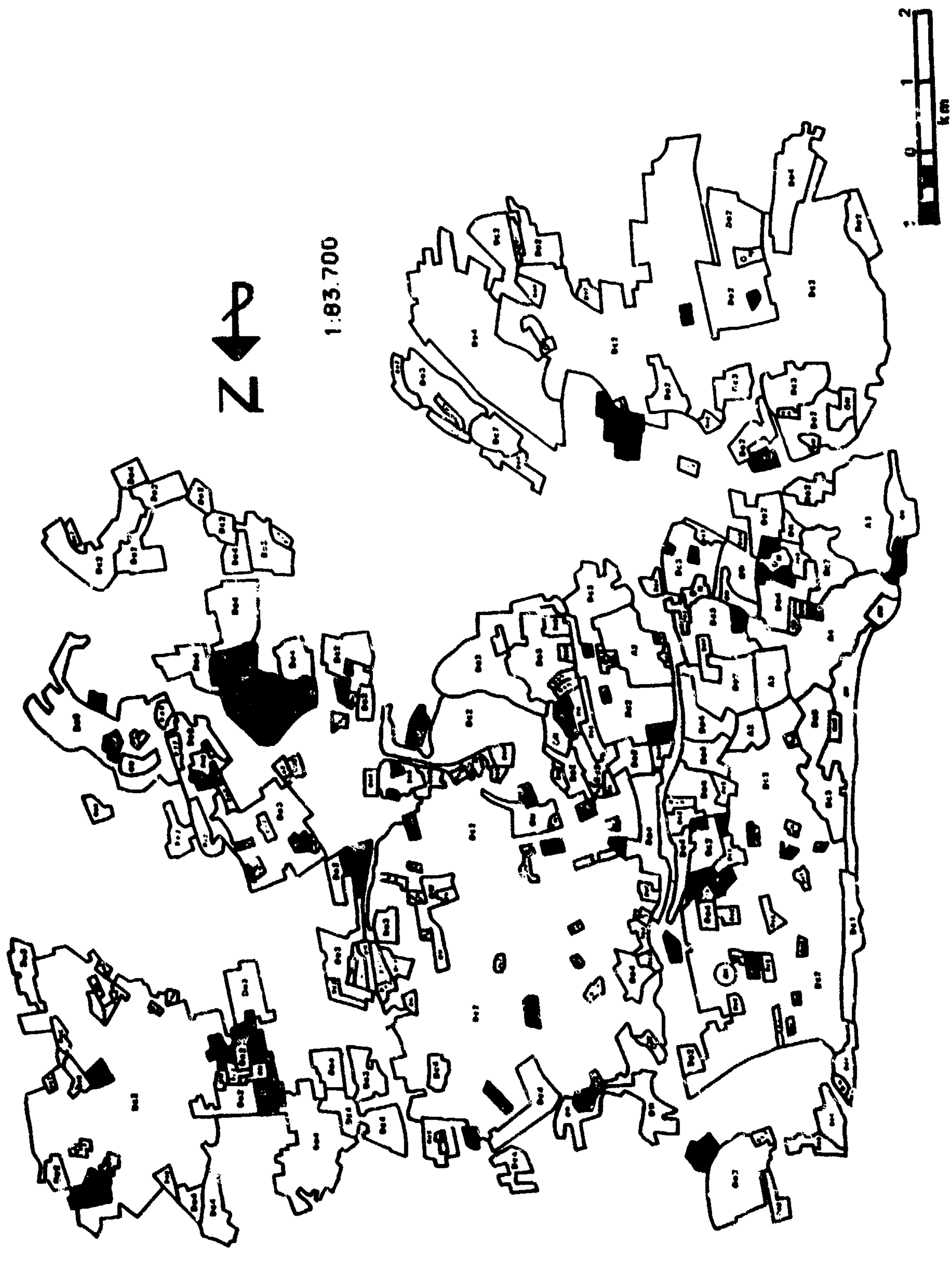
Tel Aviv-Yafo: Apartments, <75% ground coverage (Do2)



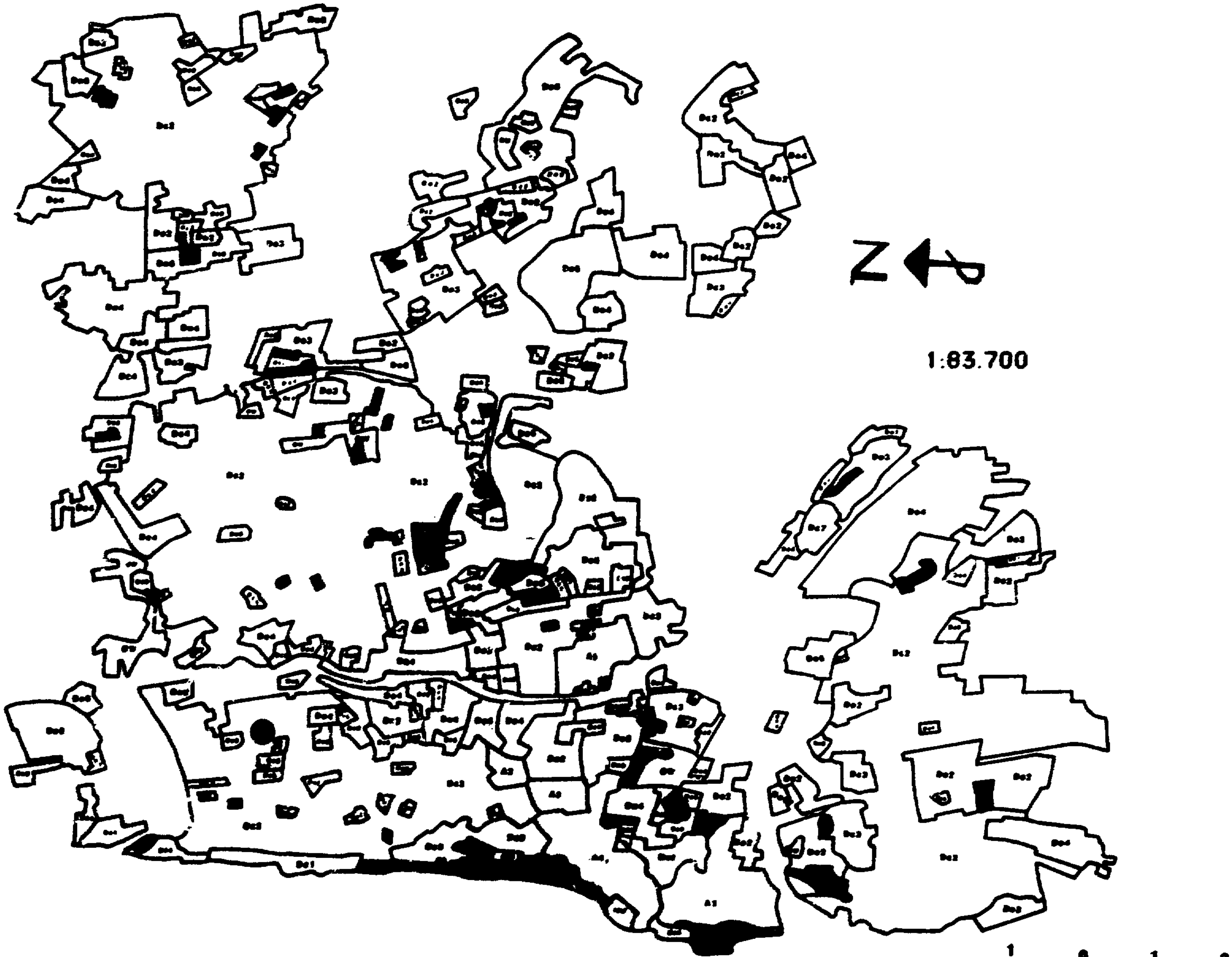
Tel Aviv-Yafo: Houses, <75% ground coverage (Do3)



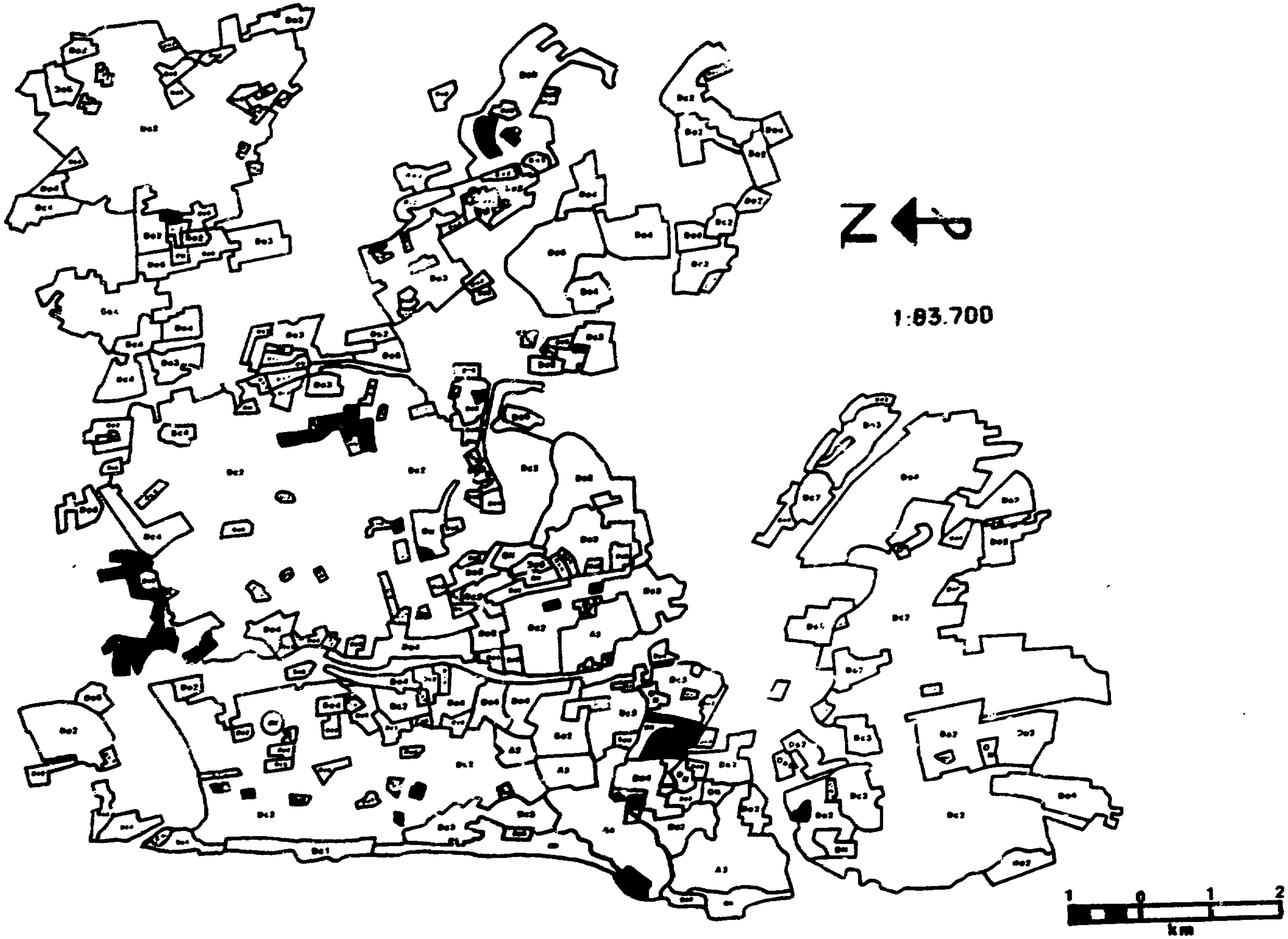
Tel Aviv-Yafo: Industrial/storage, truck-related (Do4)



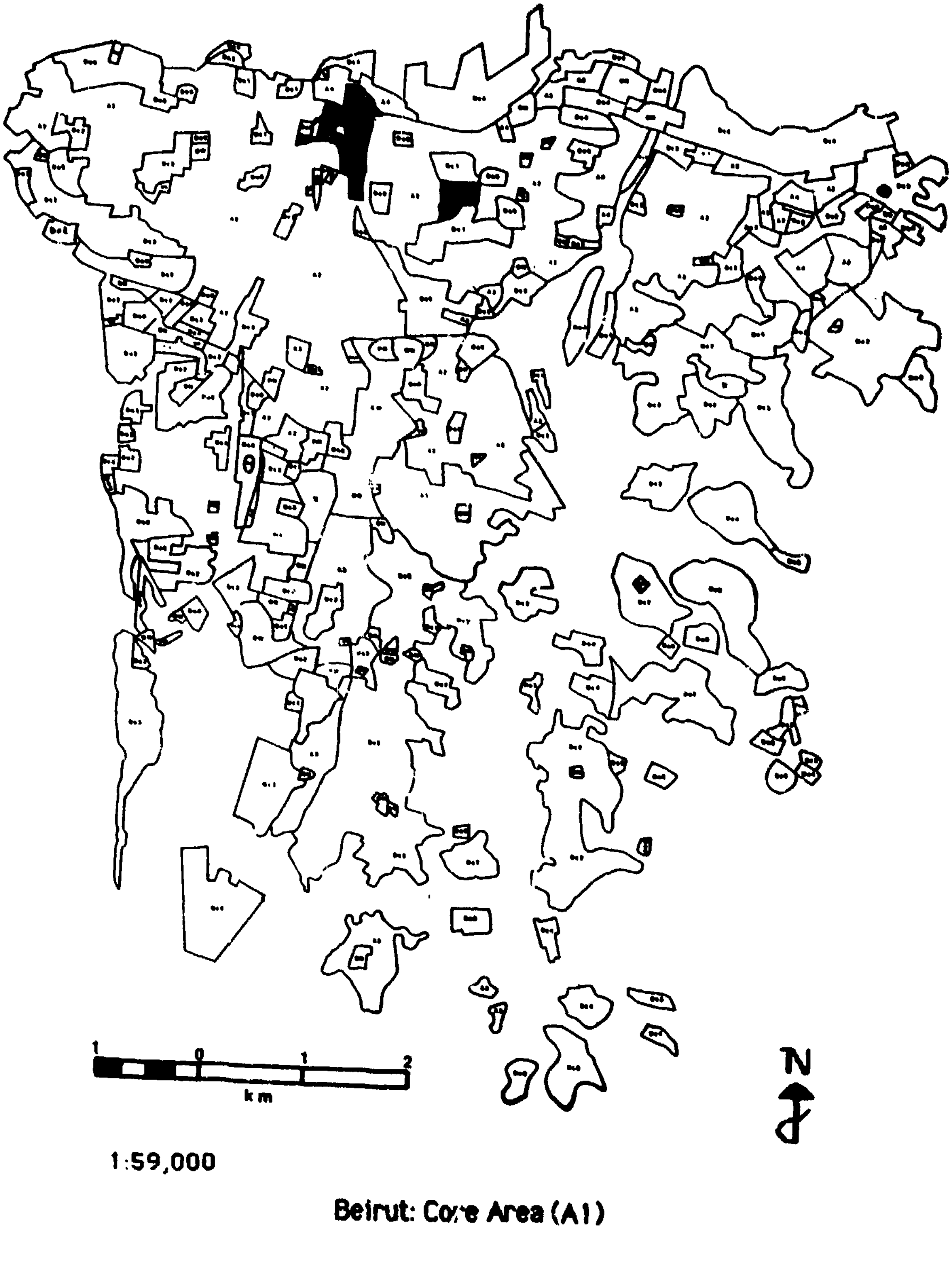
Tel Aviv-Yafo: Administrative/cultural (Do6)



Tel Aviv-Yafo: Open Space, not built upon (ON)

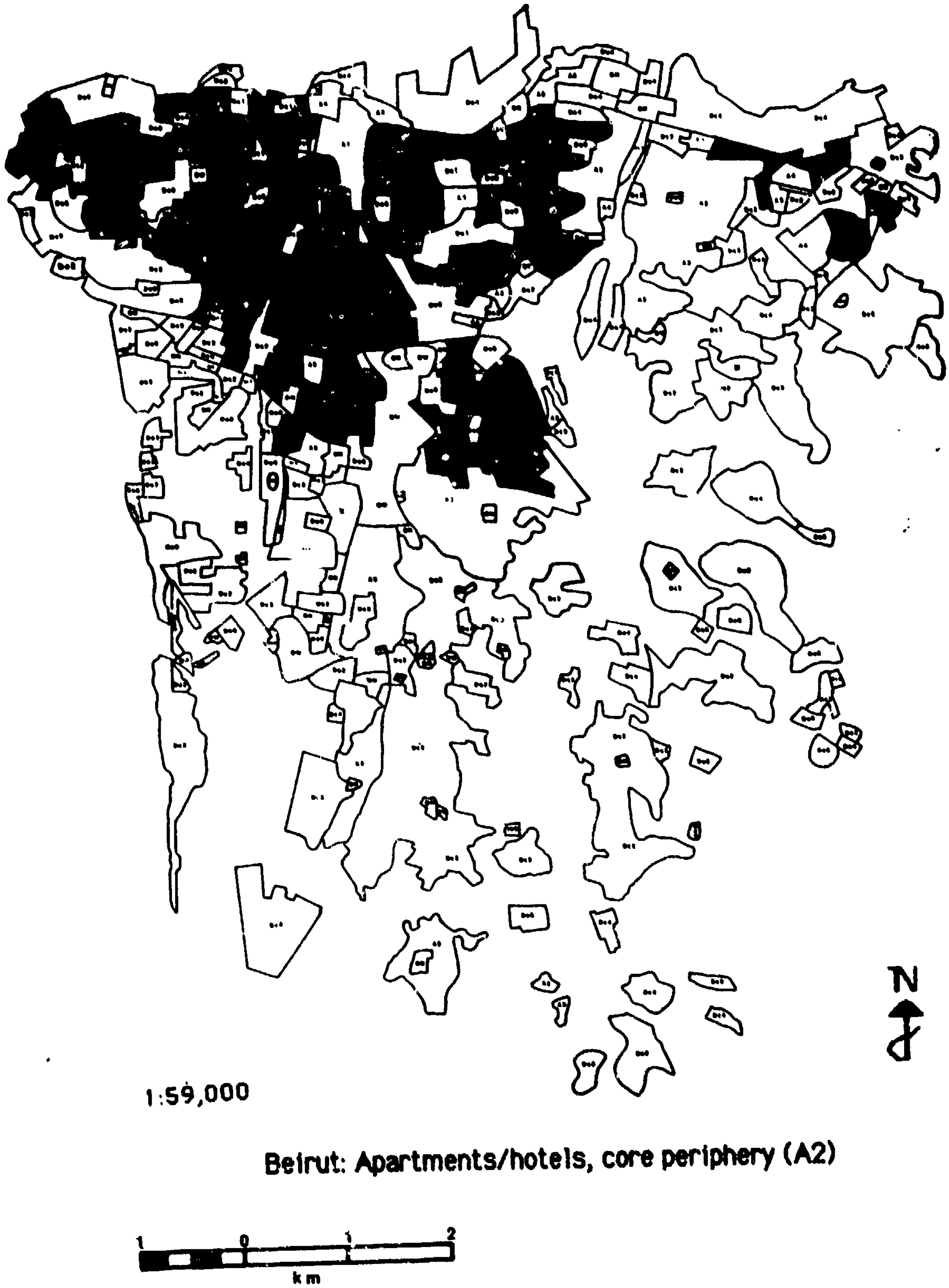


Tel Aviv-Yafo: Open Space, wooded, not built upon (OW)

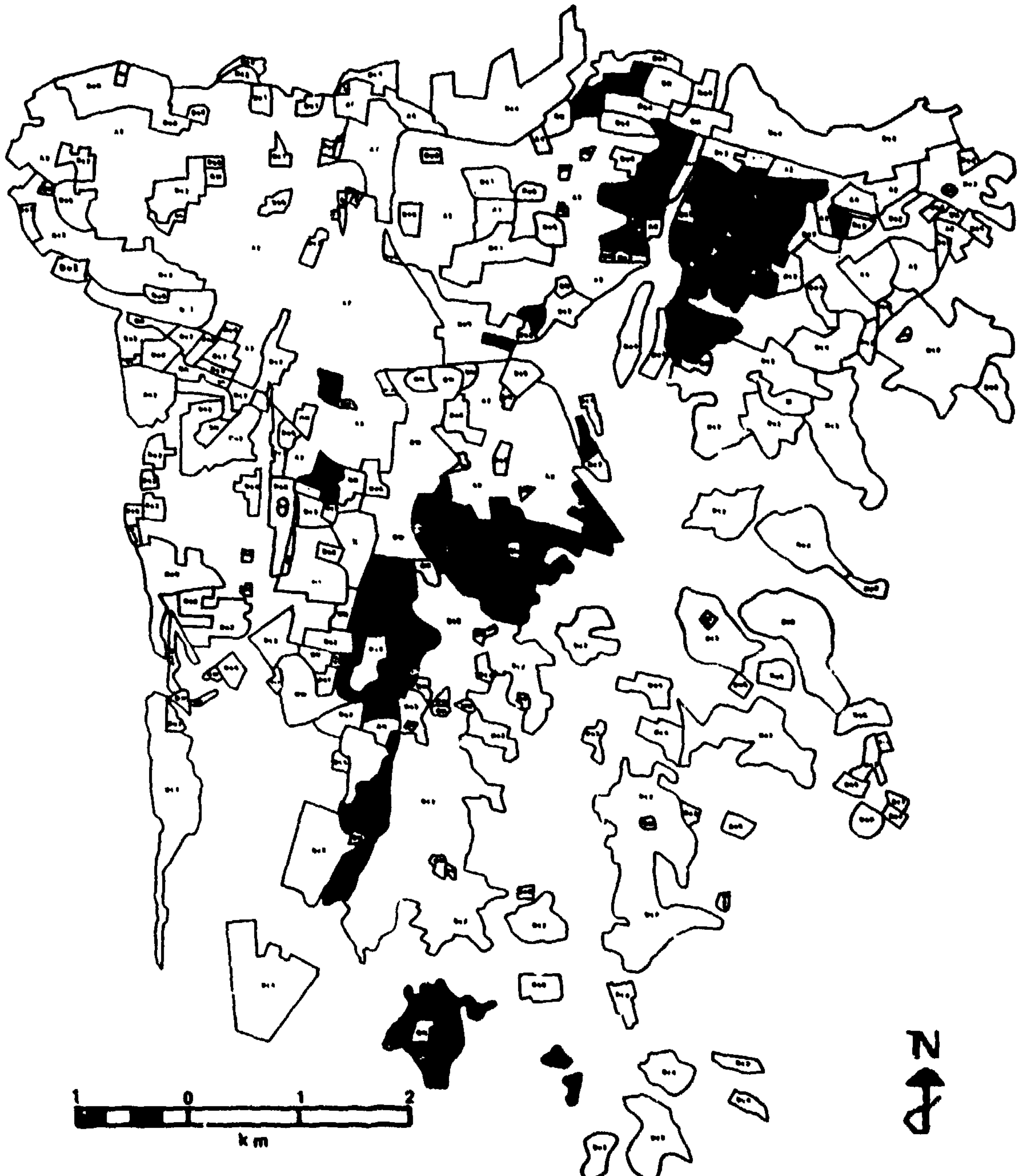


1:59,000

Beirut: Core Area (A1)

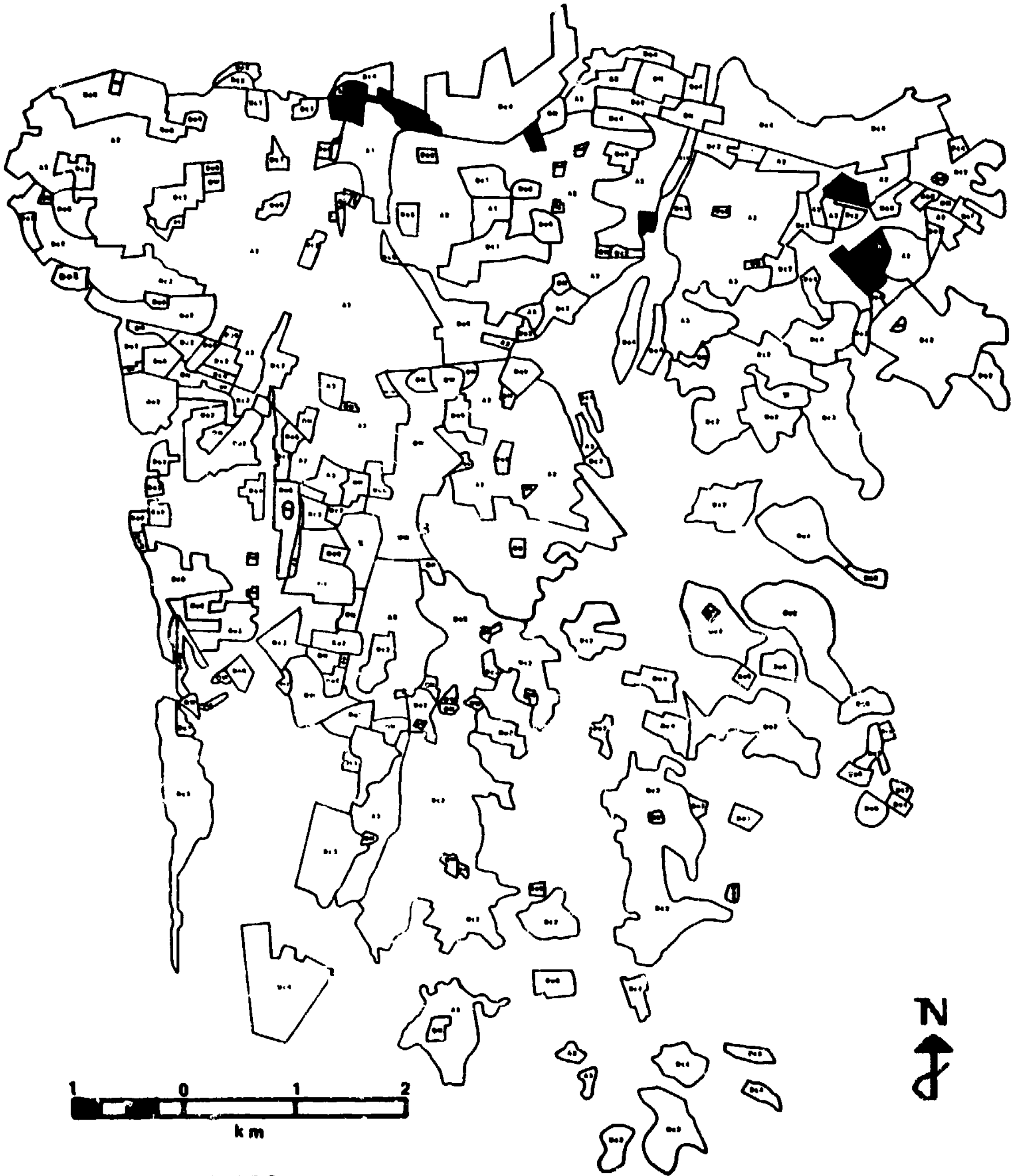


Beirut: Apartments/hotels, core periphery (A2)

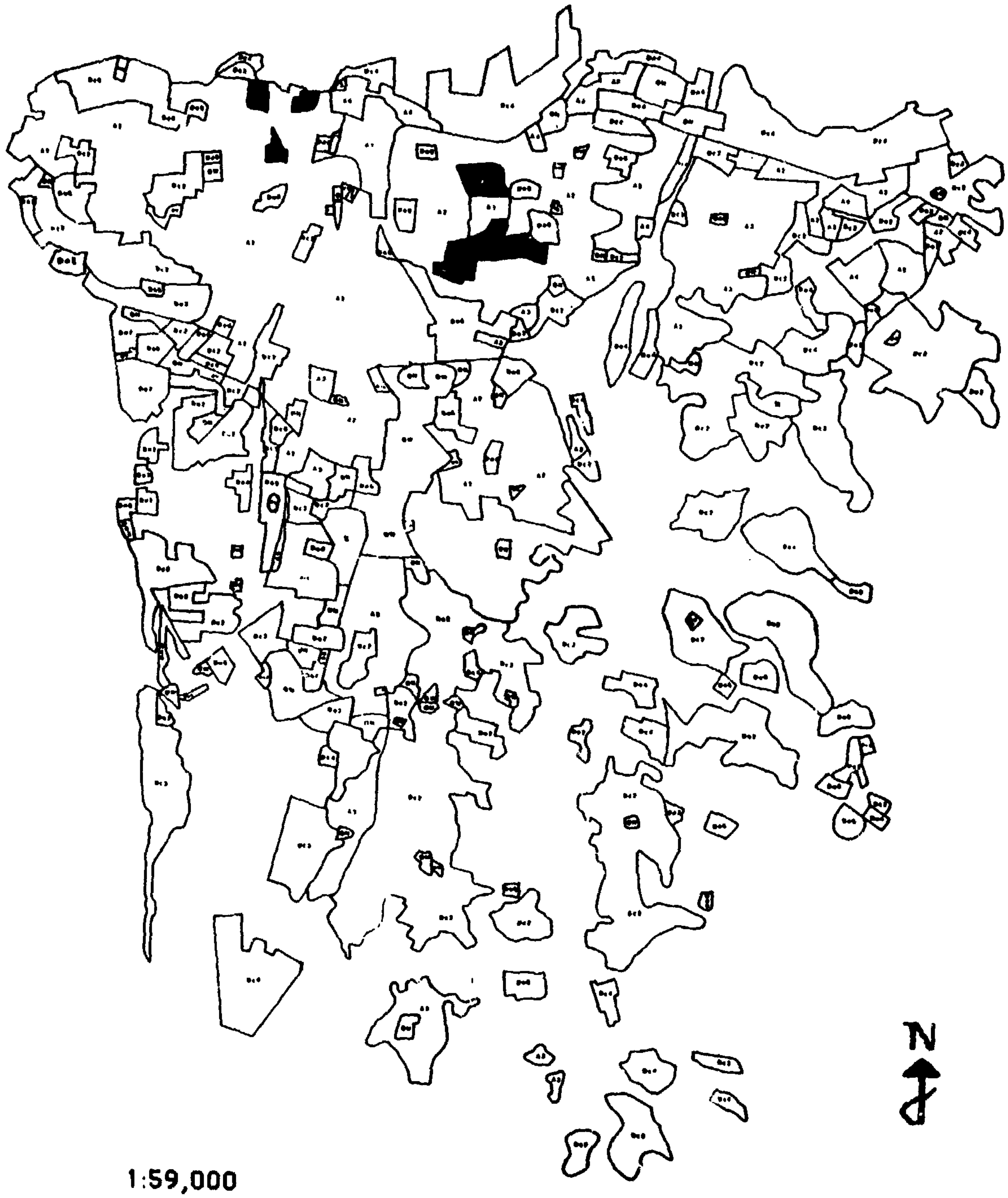


1:59,000

Beirut: Apartments/row houses (A3)



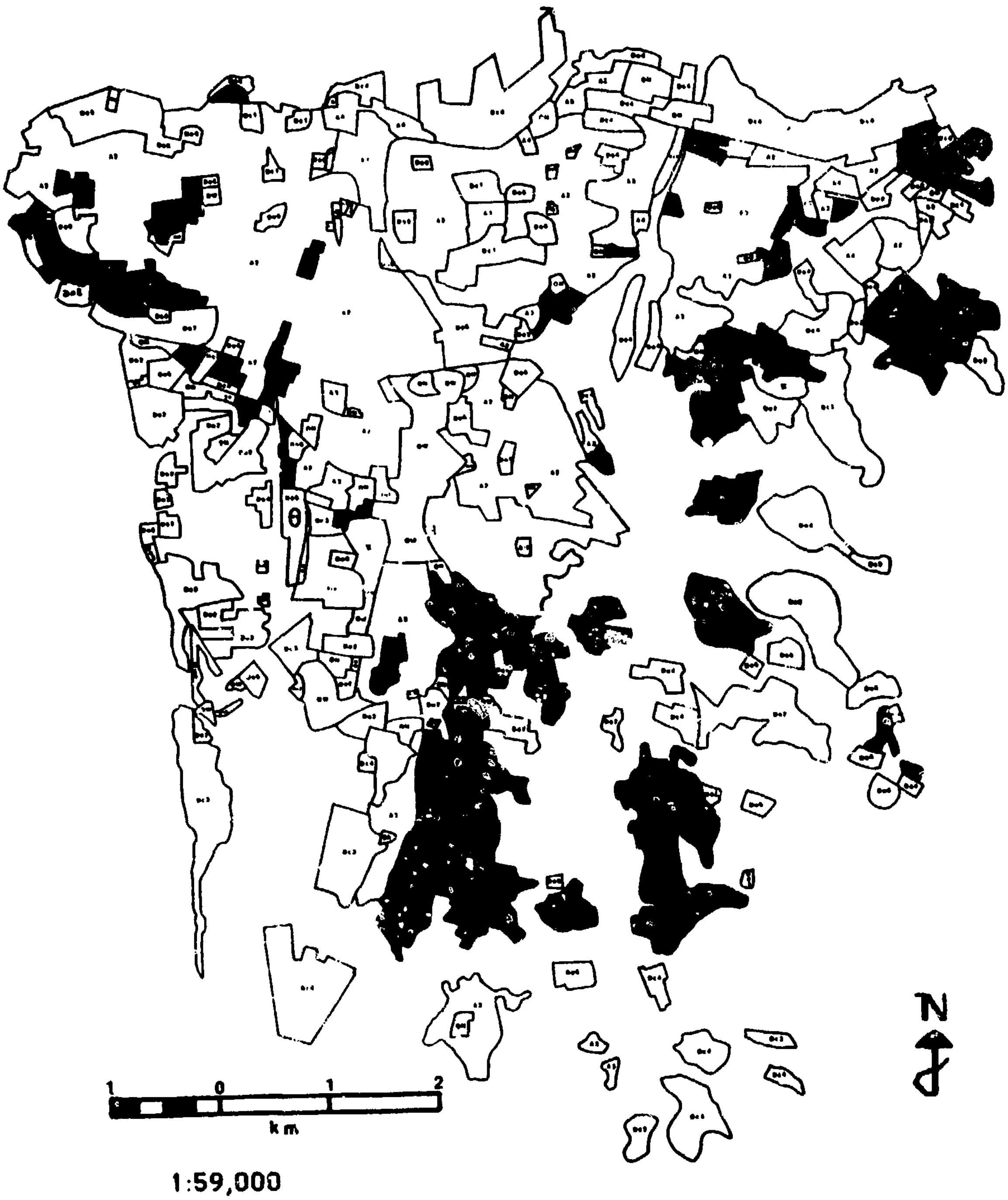
Beirut: ir⁄ustrial/storage, full urban form (A4)



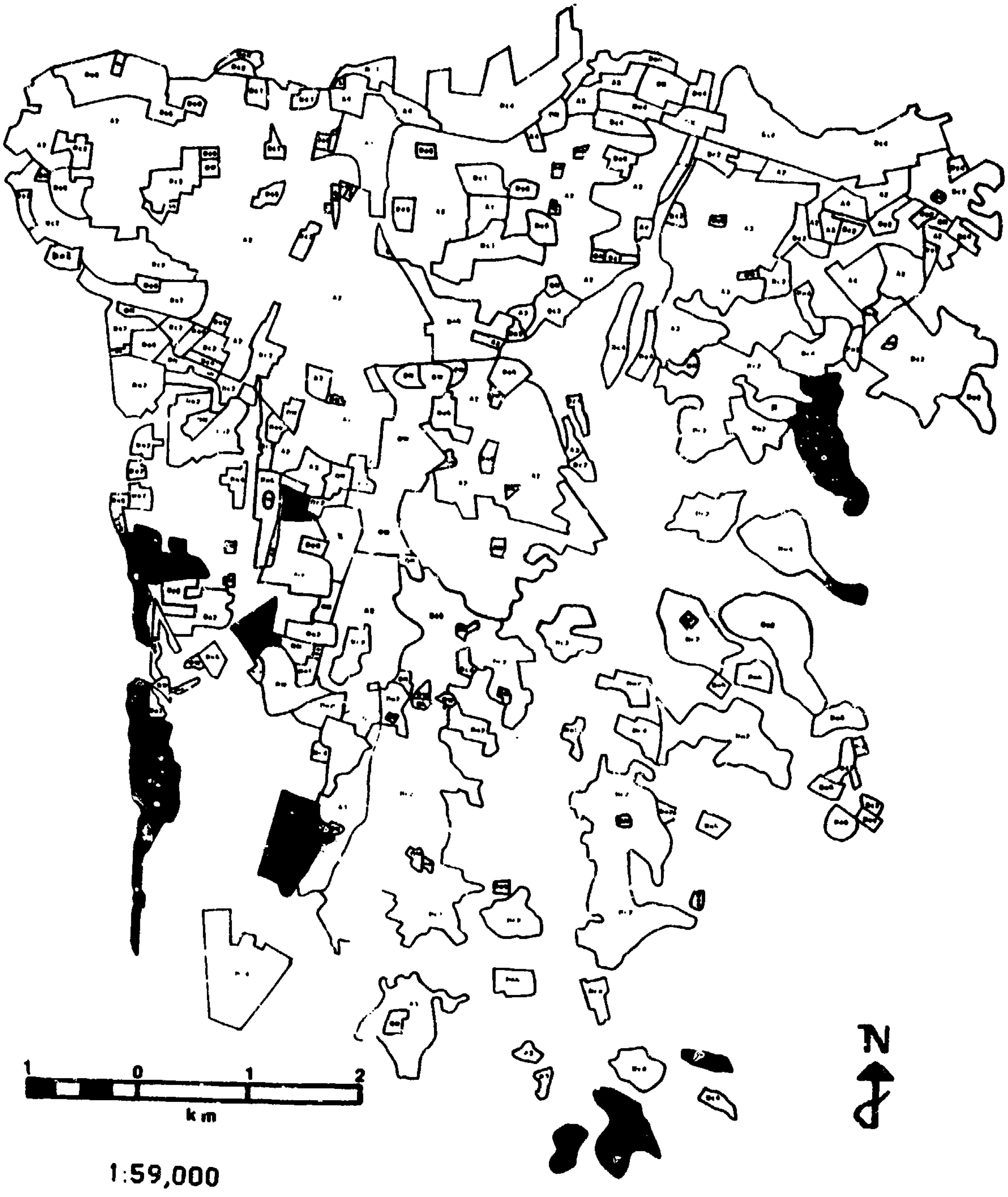
1:59,000

Beirut: Urban Redeveloped core area (Dc1)

1 0 1 2
km

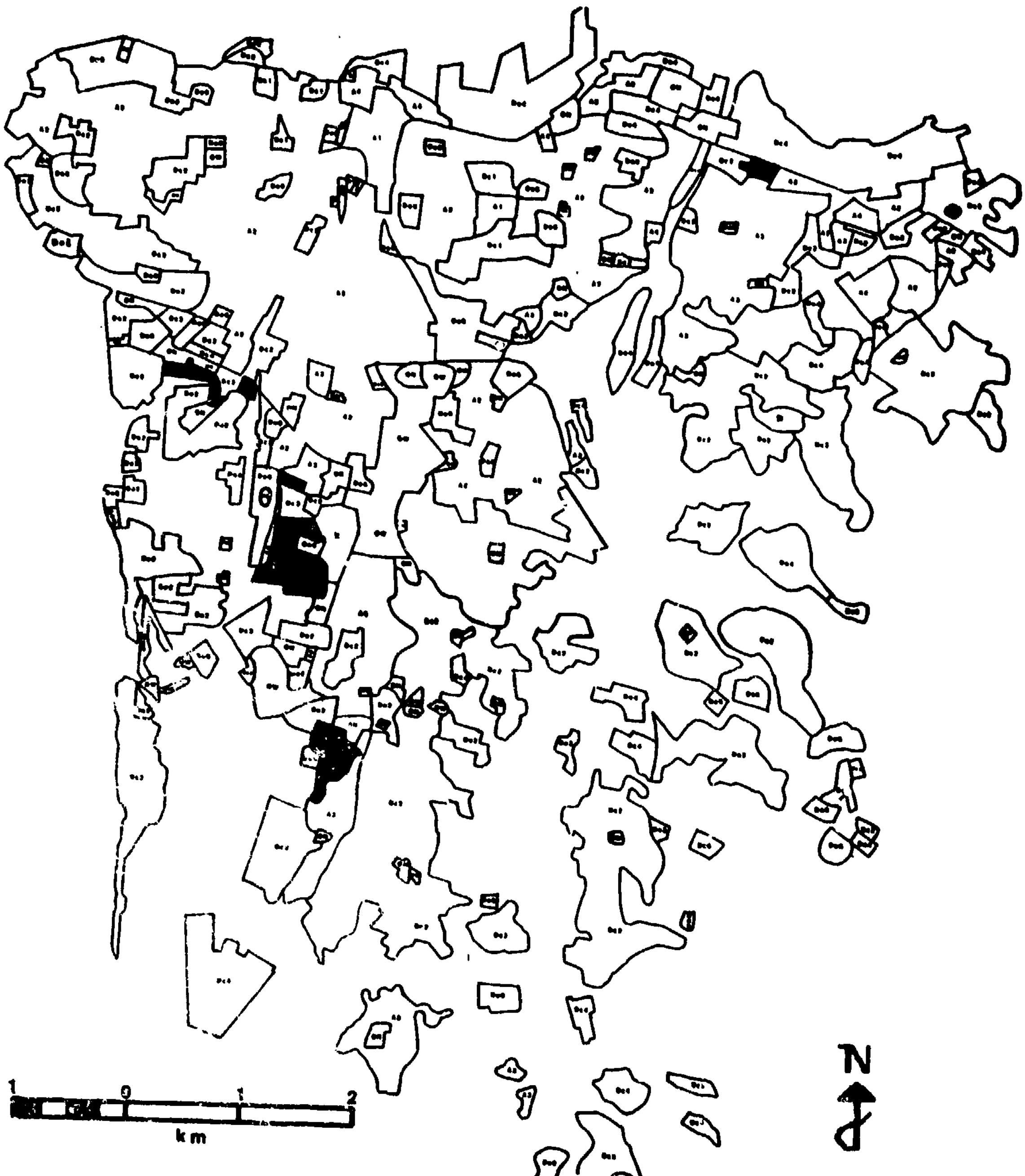


Beirut: Apartments, >75% ground coverage (Dc2)



Beirut: Houses, >75% ground coverage (Dc3)

Beirut: Industrial/storage, RP or dock-related (Dc4)

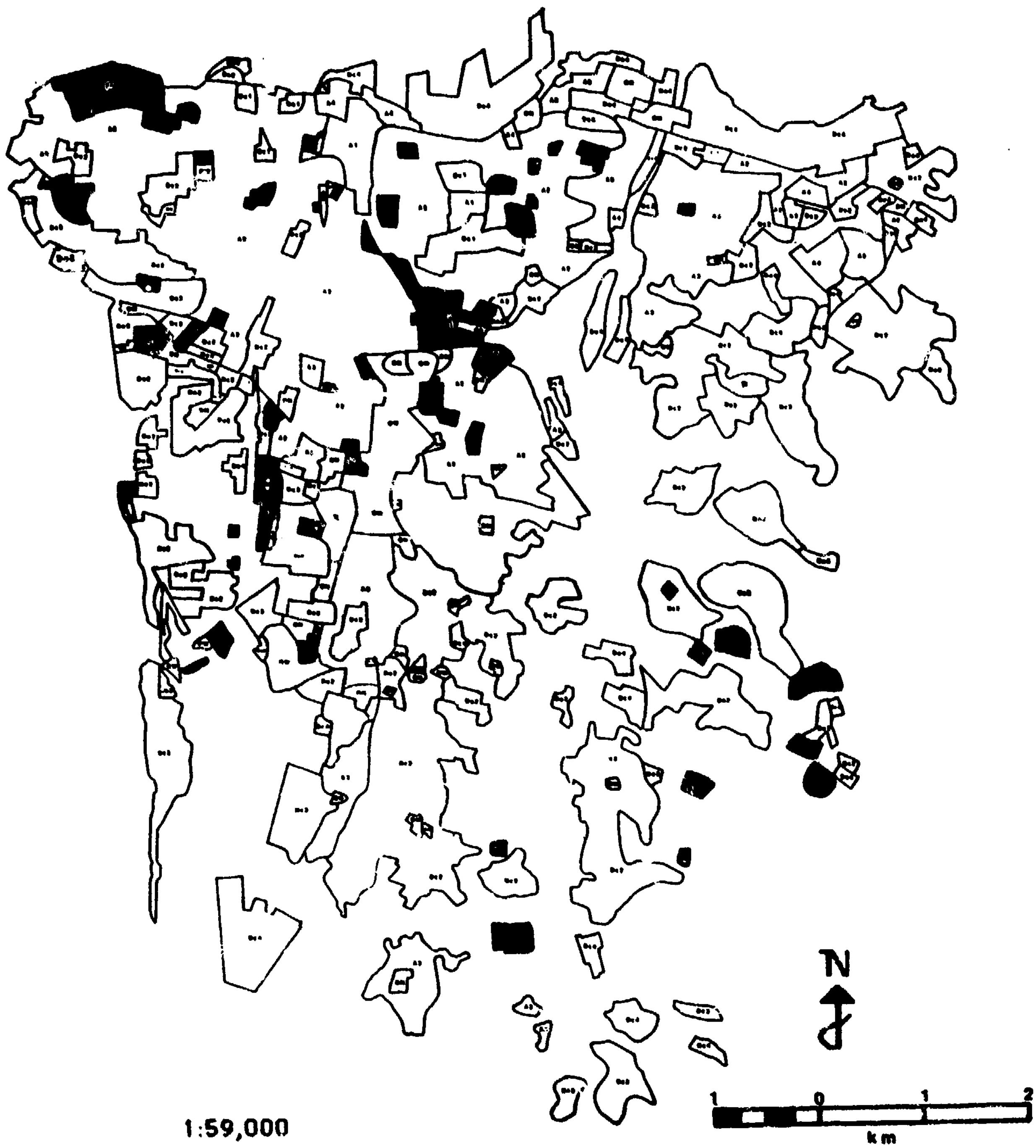


1.59,000

Beirut: Shanty Towns (Dc8)

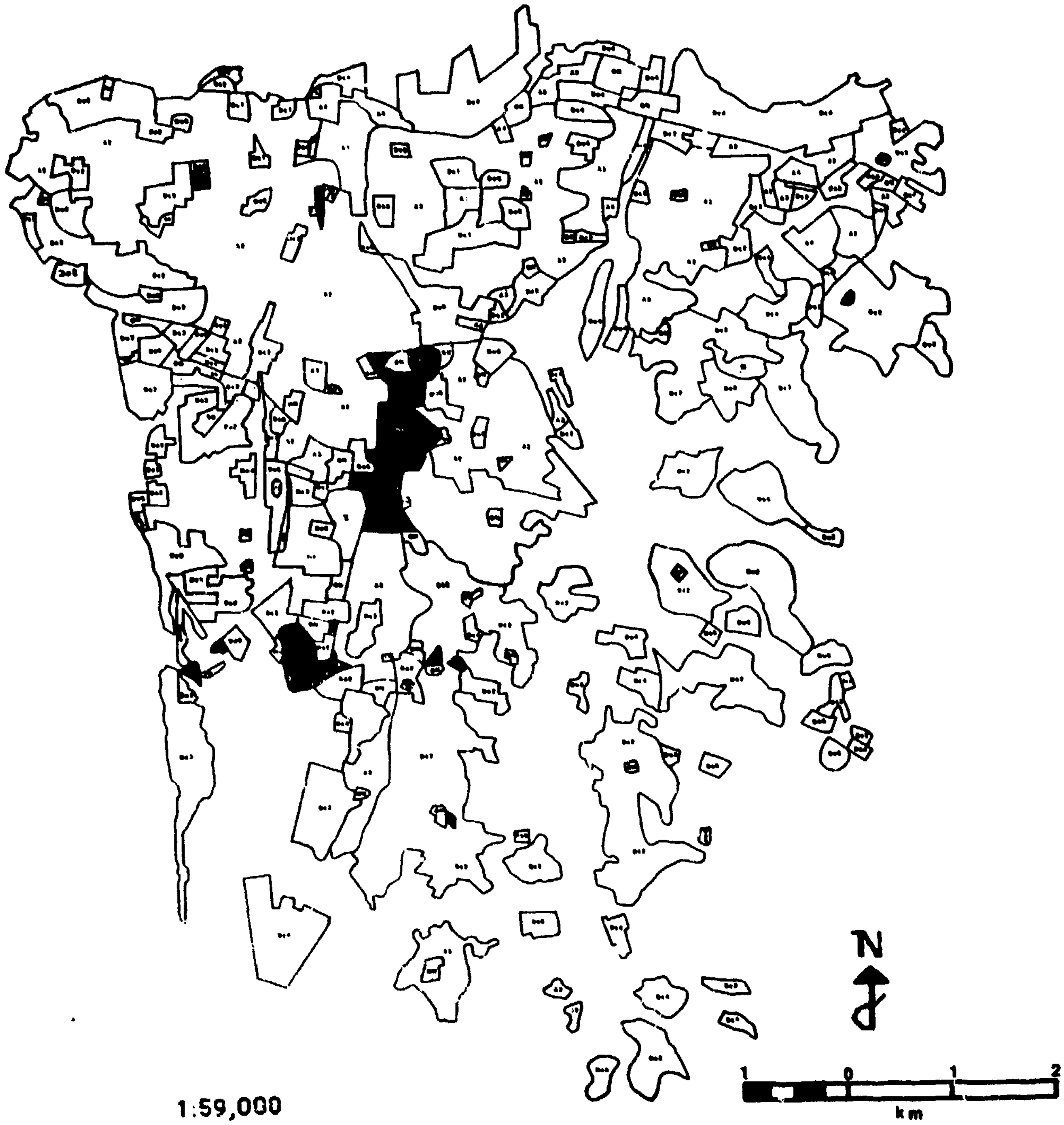
Beirut: Apartments, <75% ground coverage (Do2)

Beirut: Industrial/storage, truck-related (Do4)

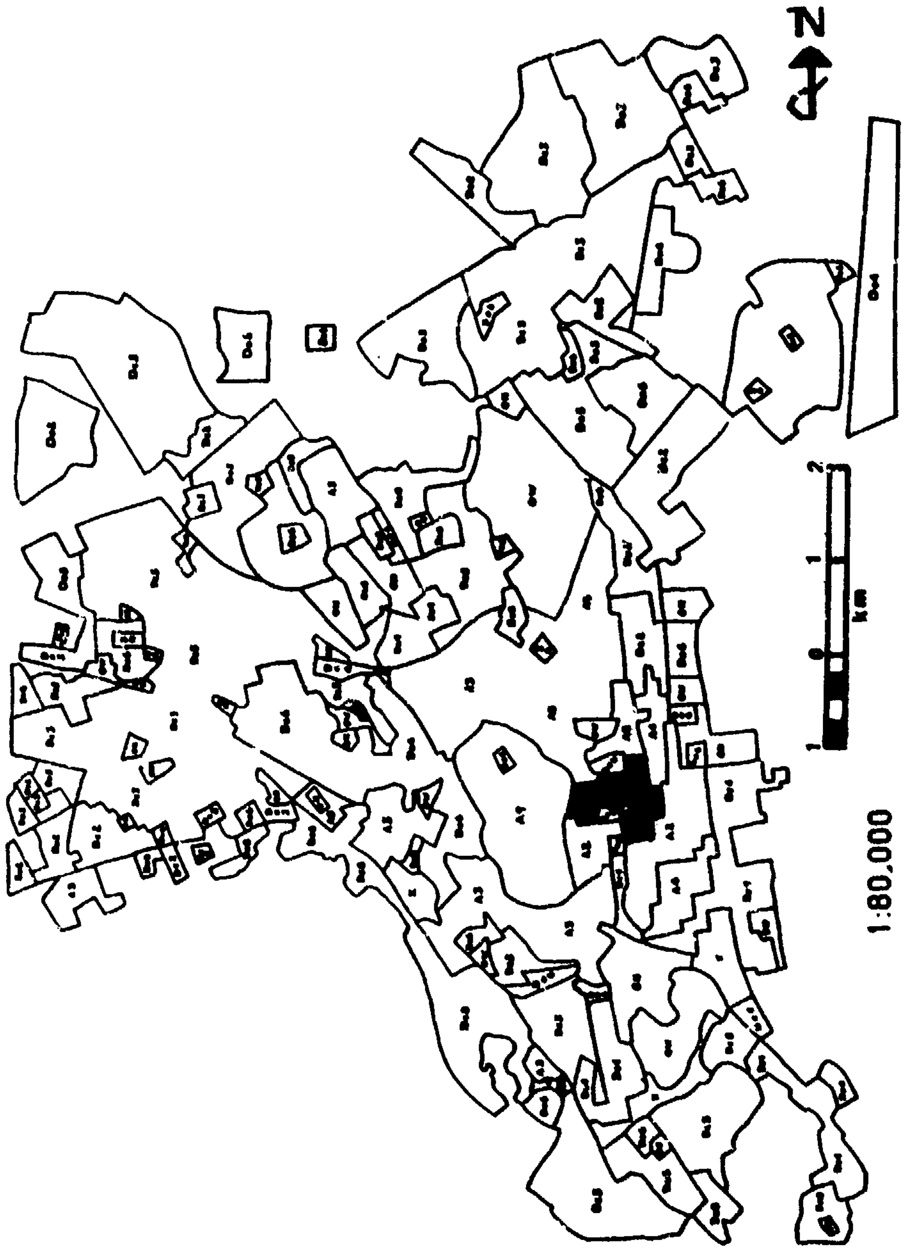


Beirut: Administrative/cultural (Do6)

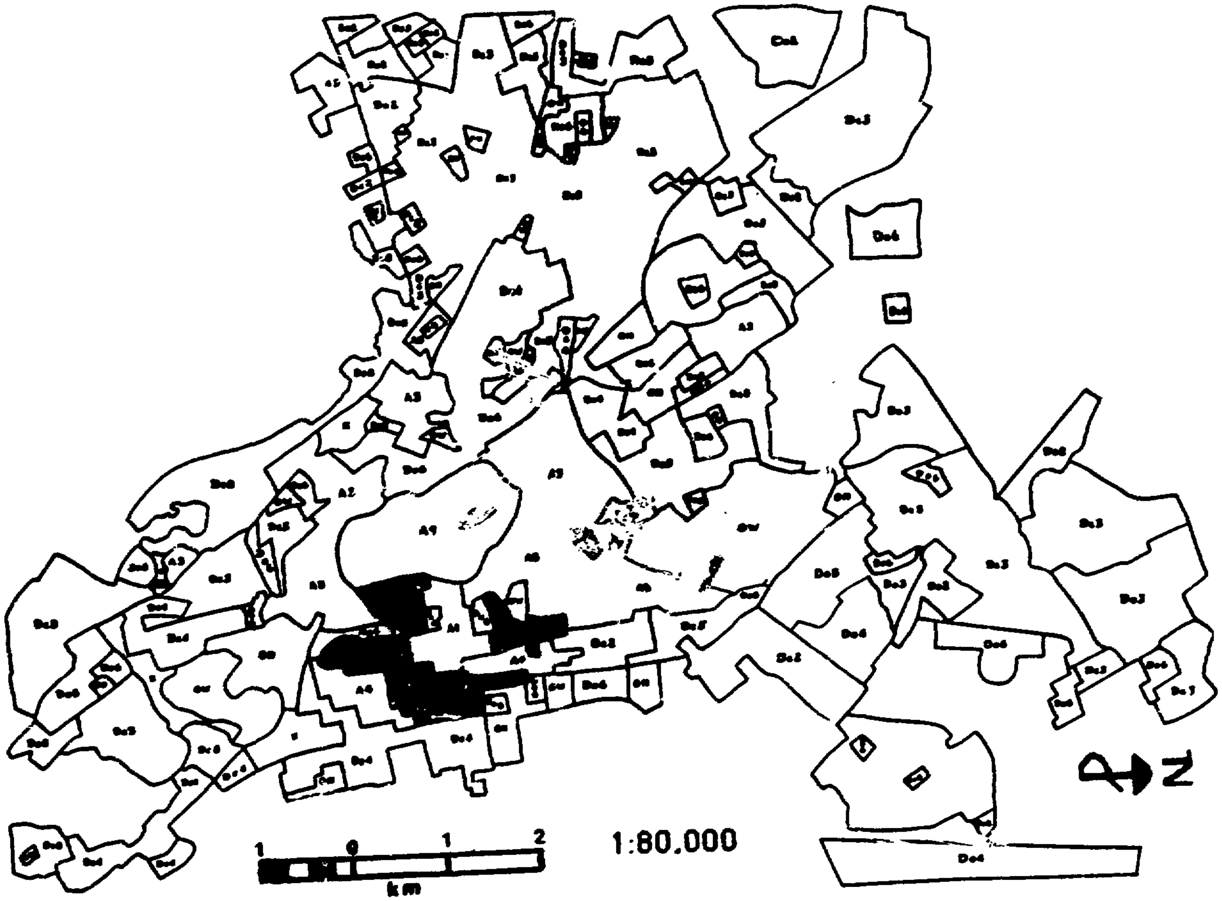
Beirut: Open Space, not built upon (ON)



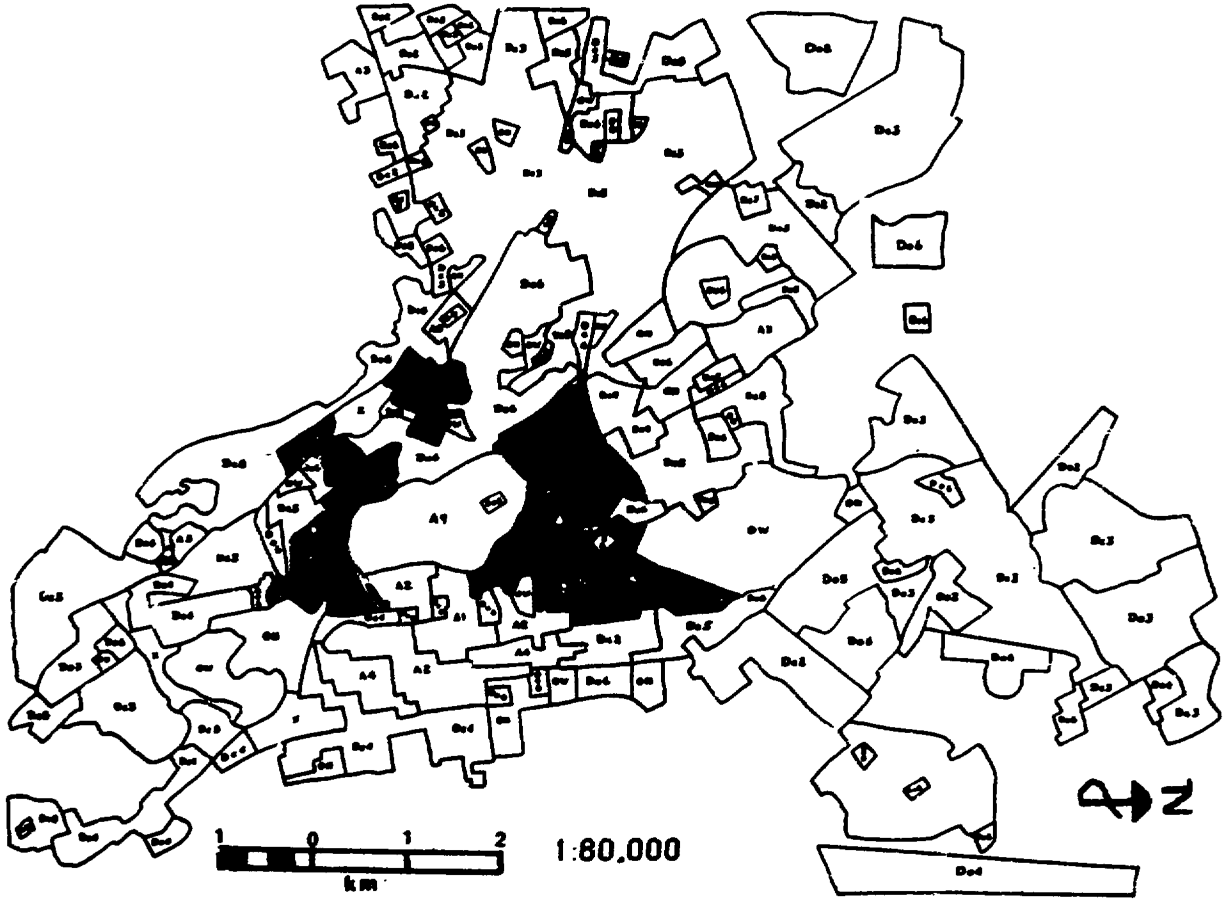
Beirut: Open Space, wooded, not built upon (OW)



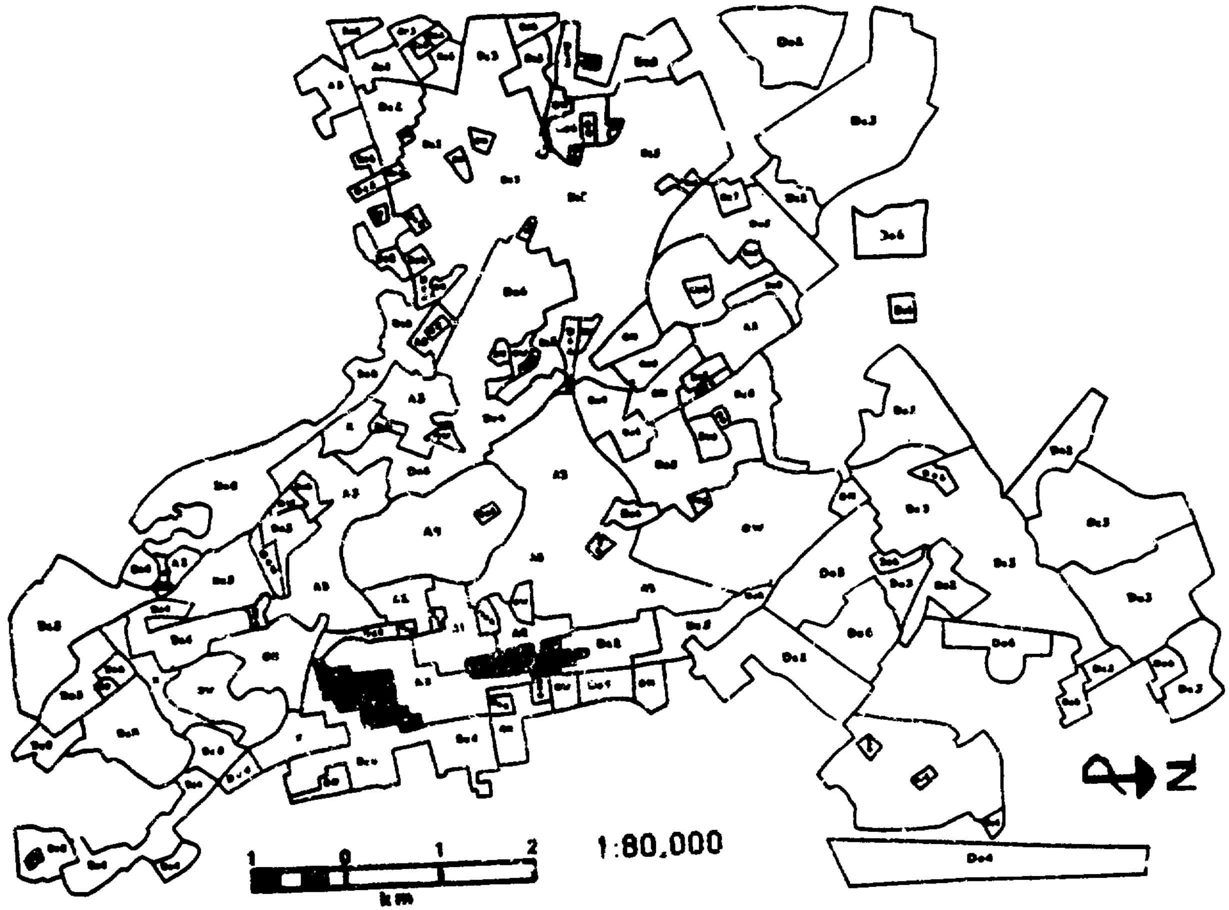
Tunis: Core Area (A1)



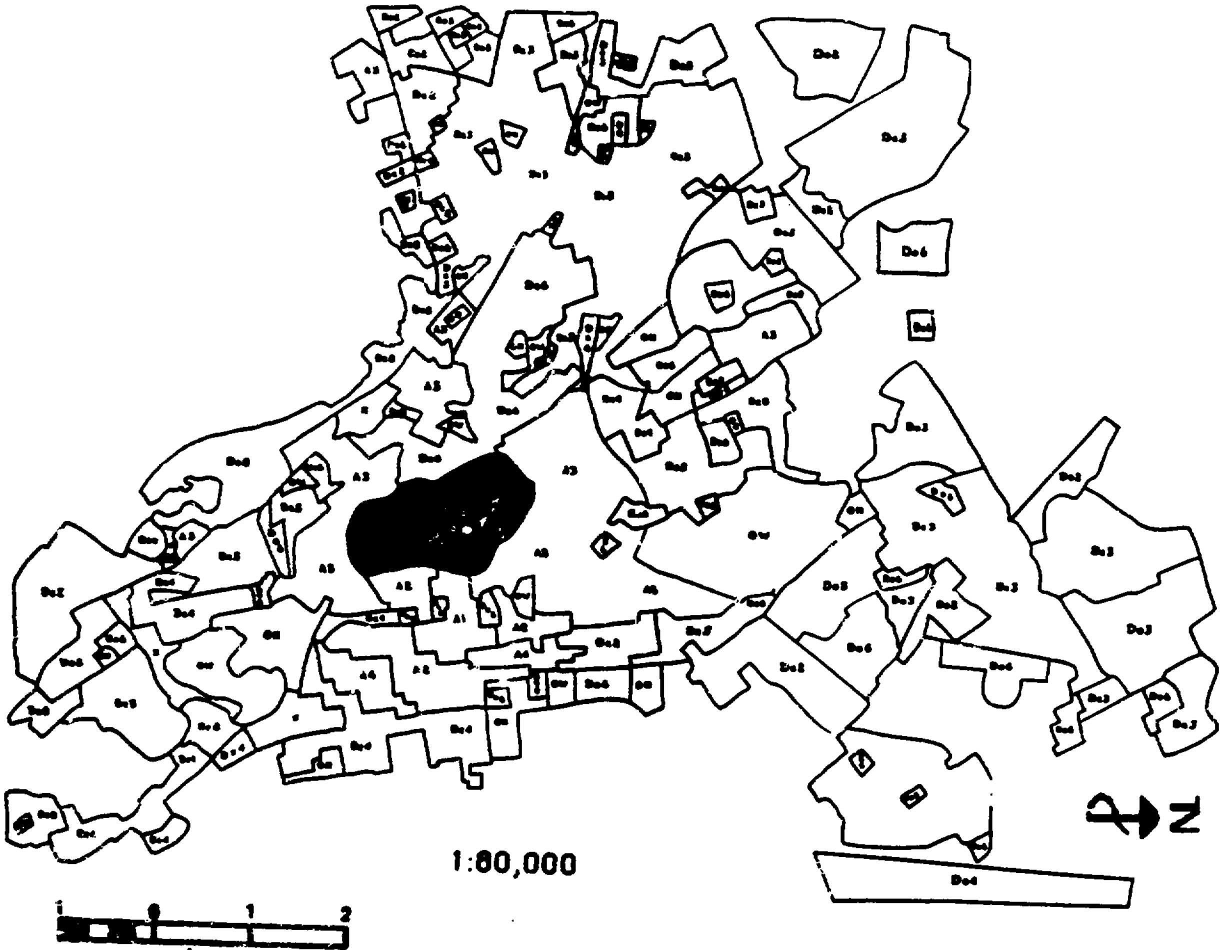
Tunis: Apartments/hotels, core periphery (A2)



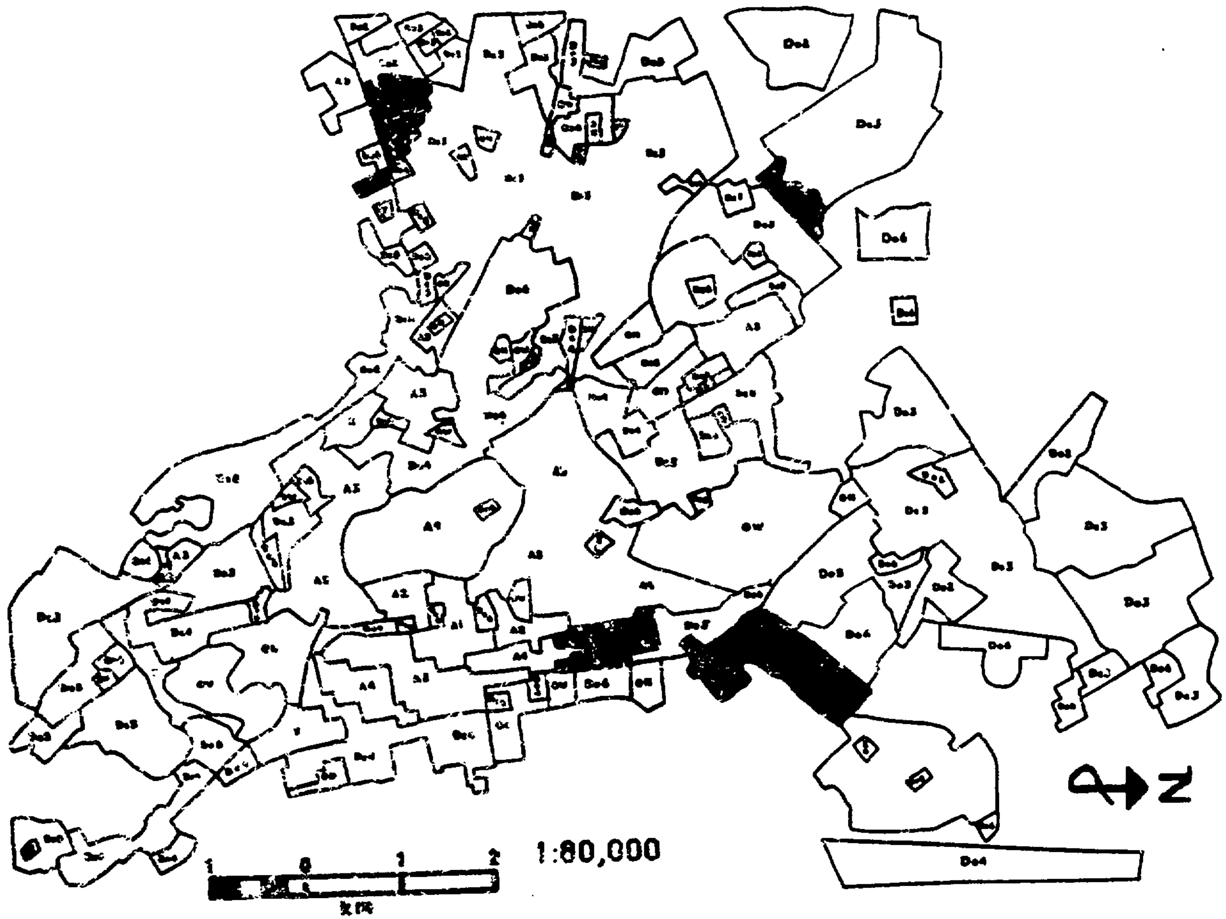
Tunis: Apartments/row houses (A3)



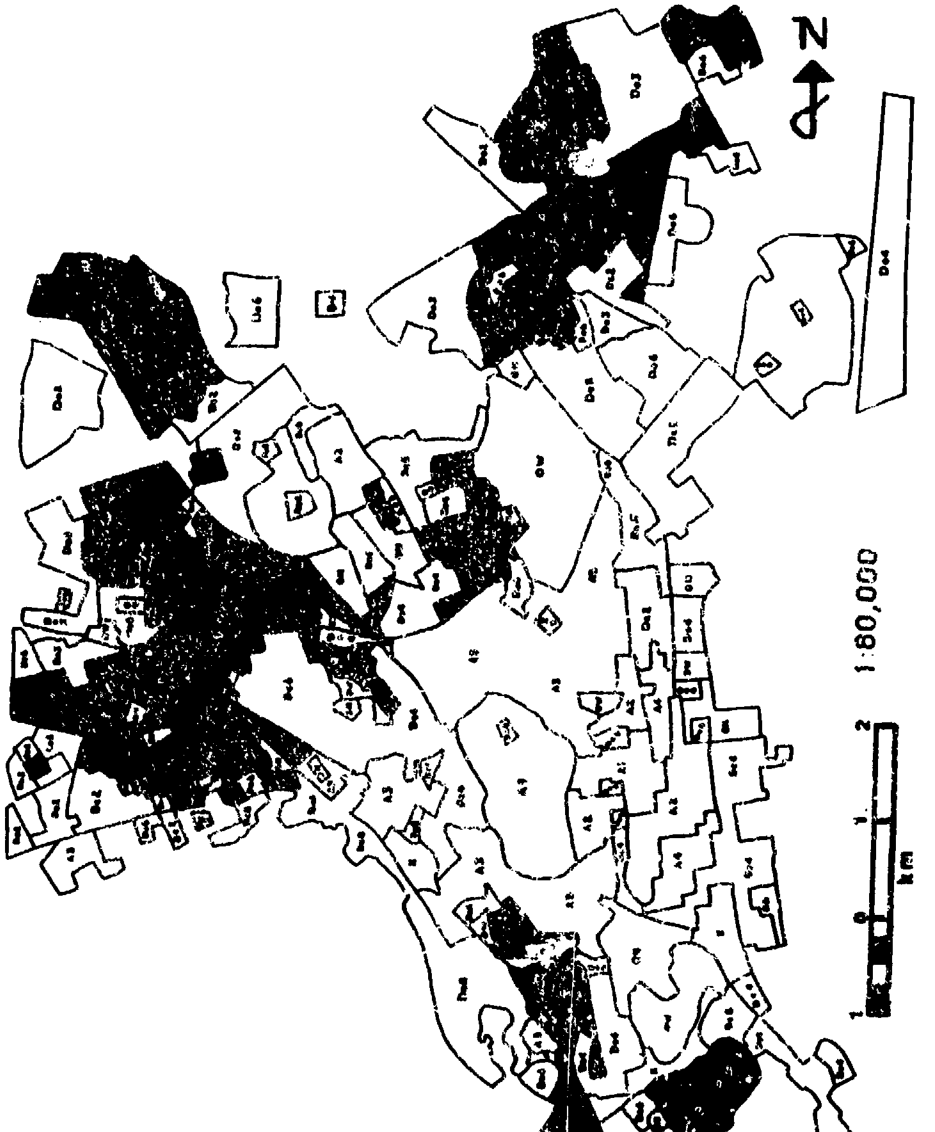
Tunis: Industrial/storage, full urban form (A4)



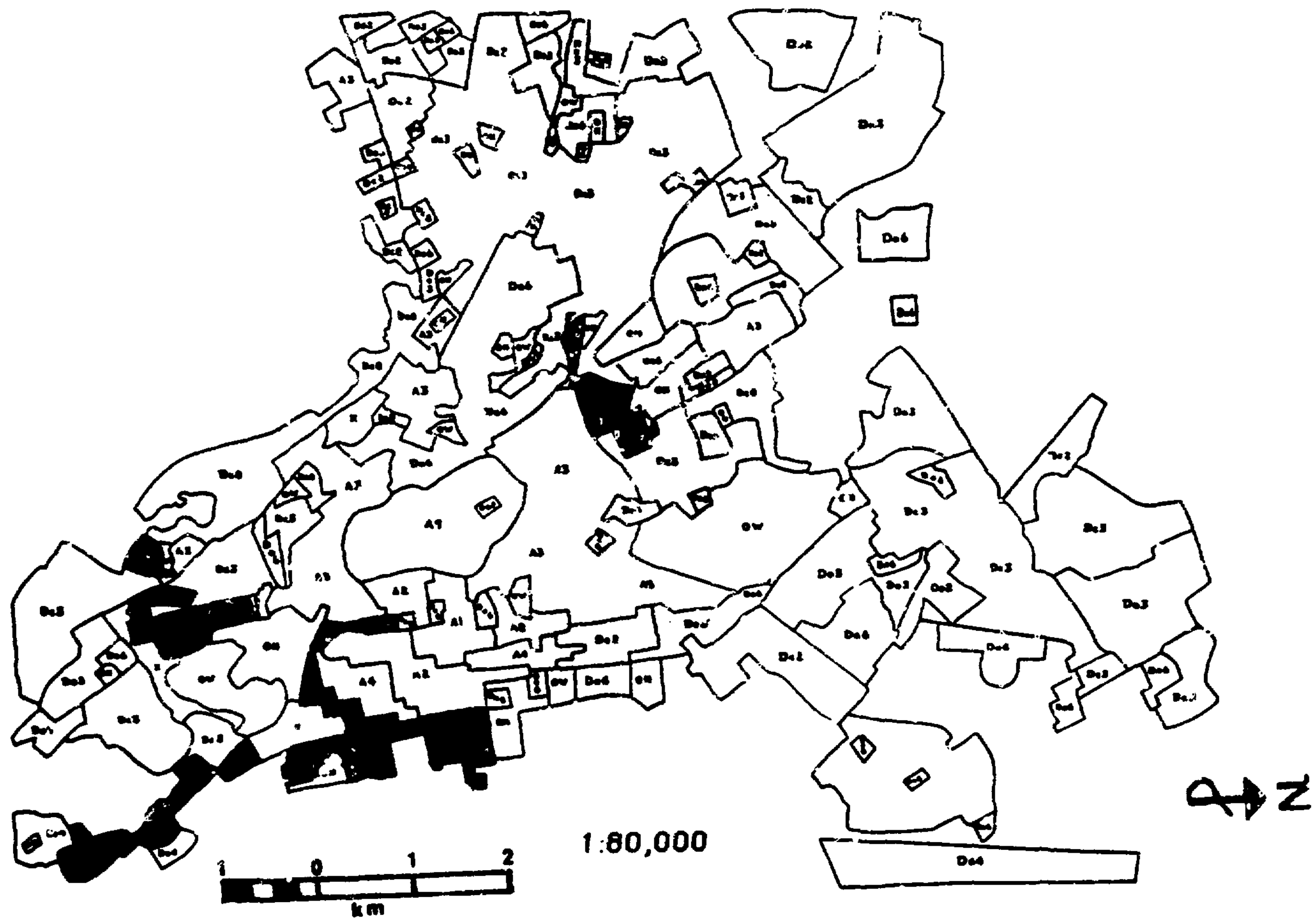
Tunis: Old Core, vestigial (A9)



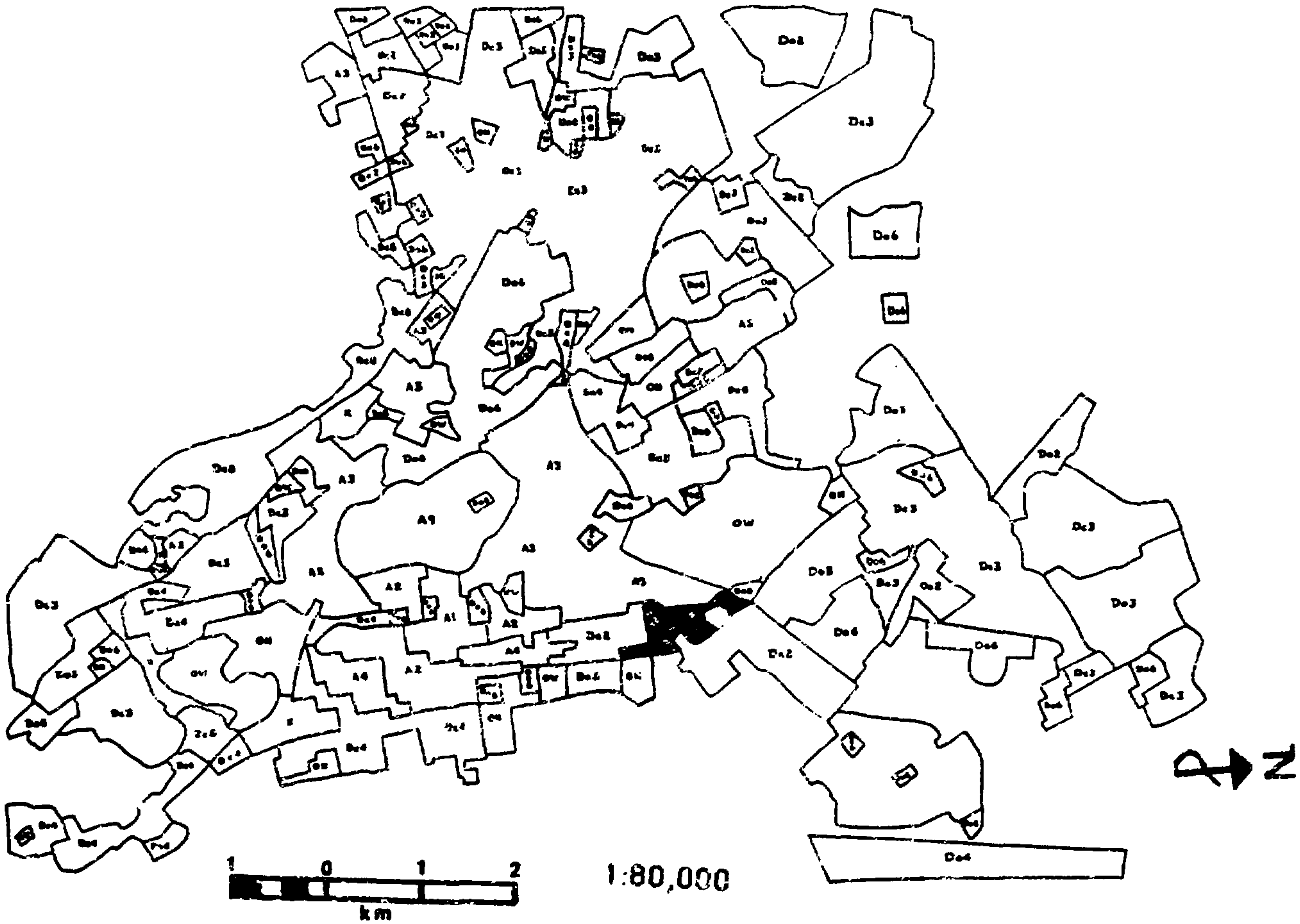
Tunis: Apartments, >75% ground coverage (Dc2)



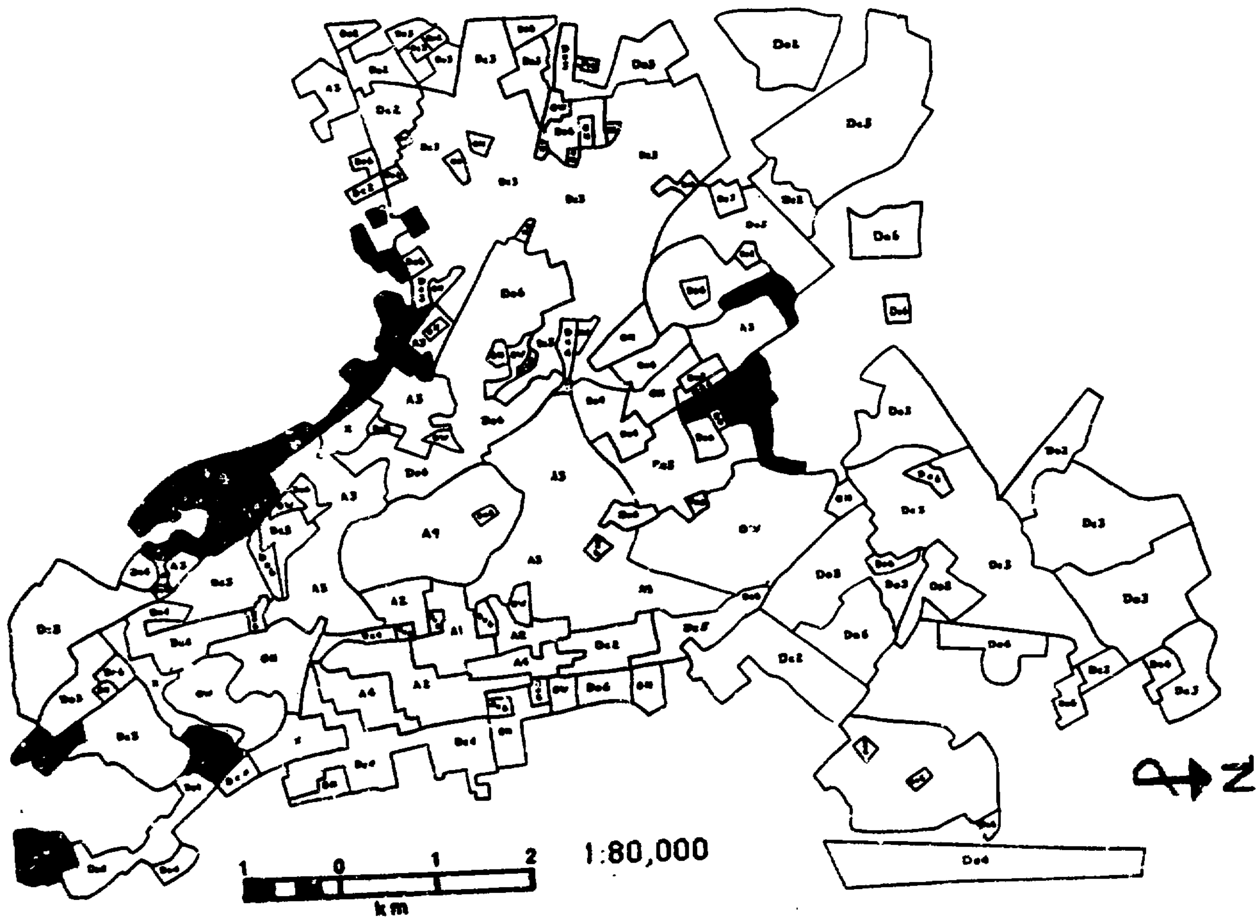
Tunis: Houses, >75% ground coverage (Dc3)



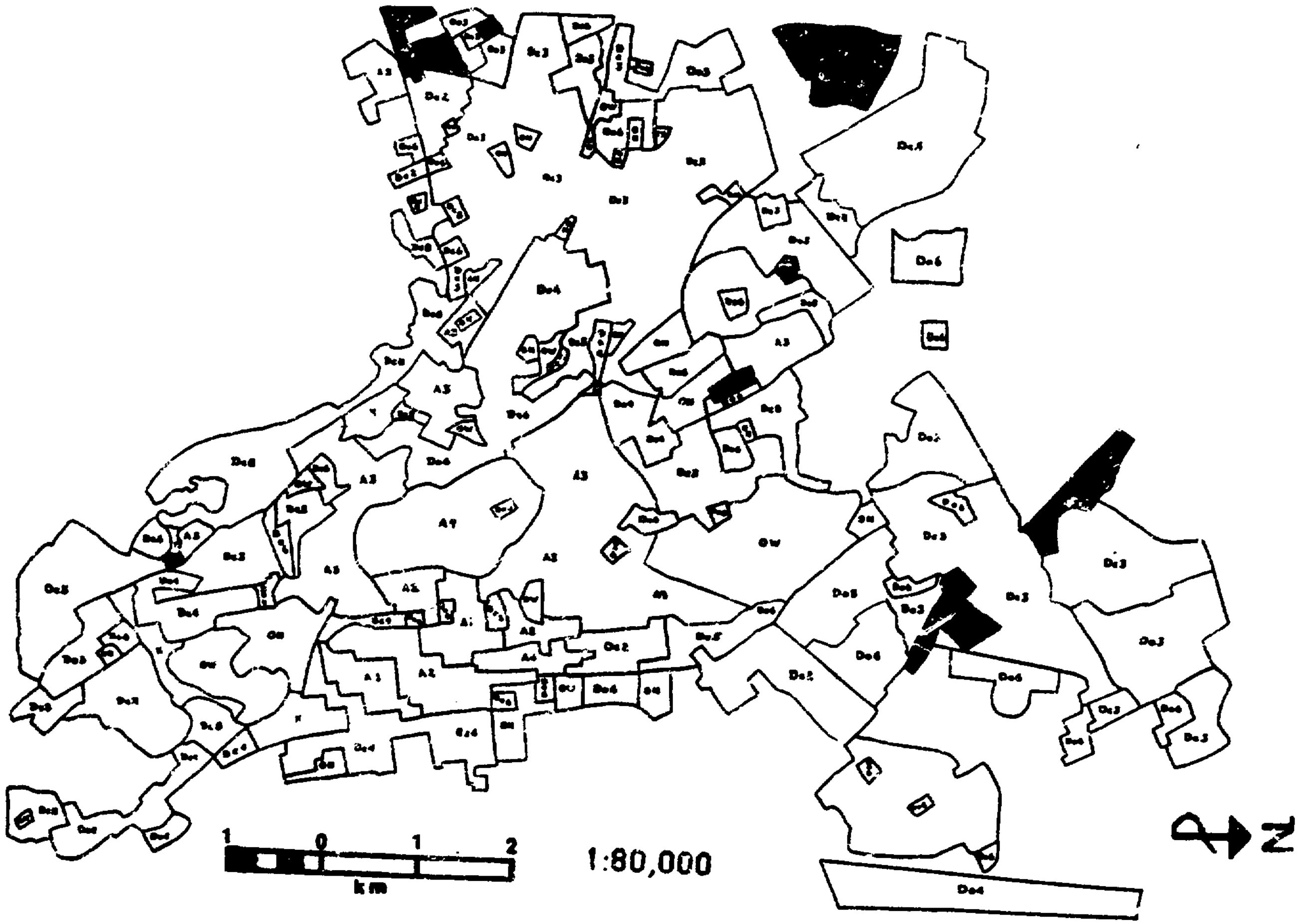
Tunis: Industrial/storage, RR or dock-related (Dc4)



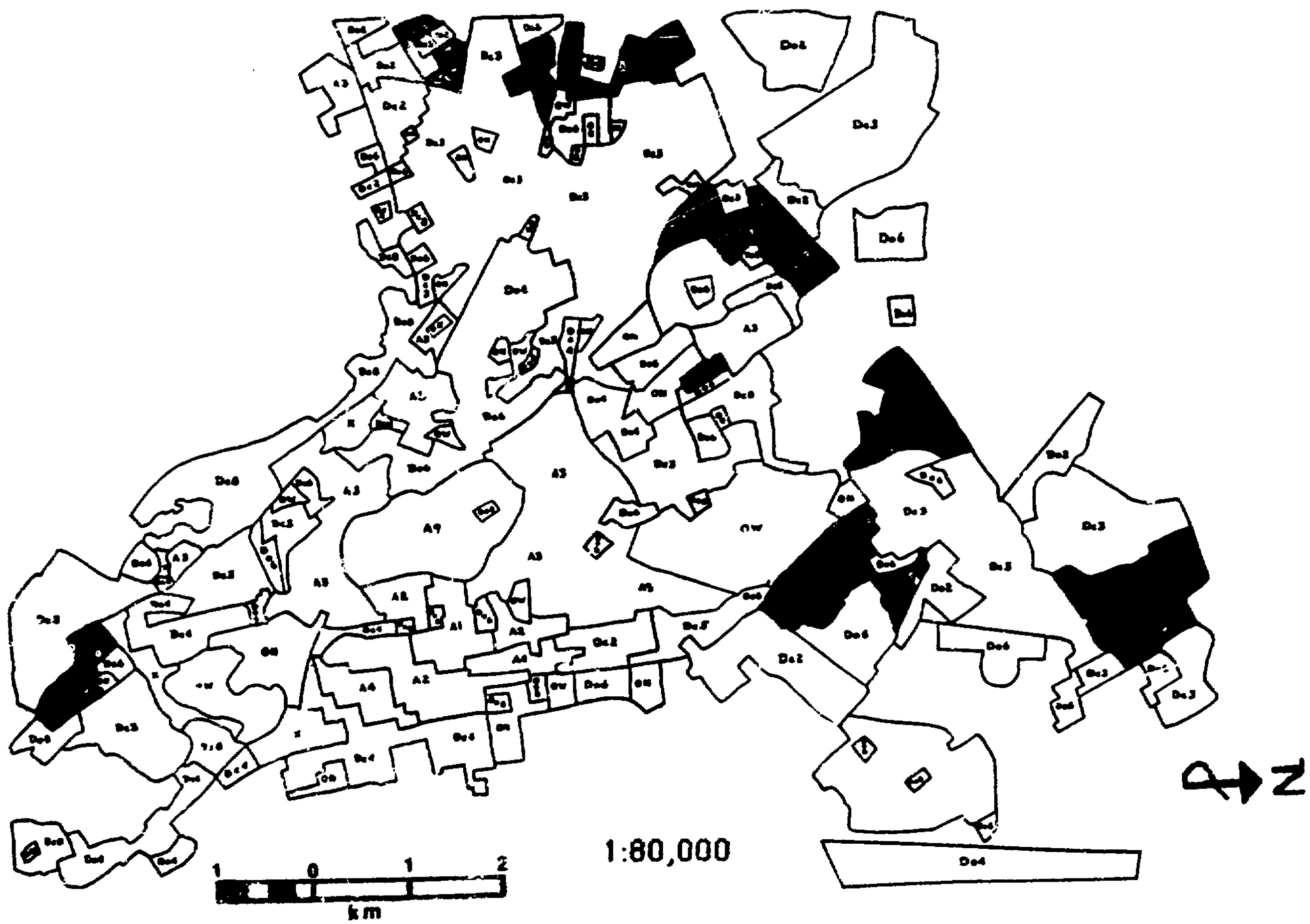
Tunis: Outer City (Dc5)



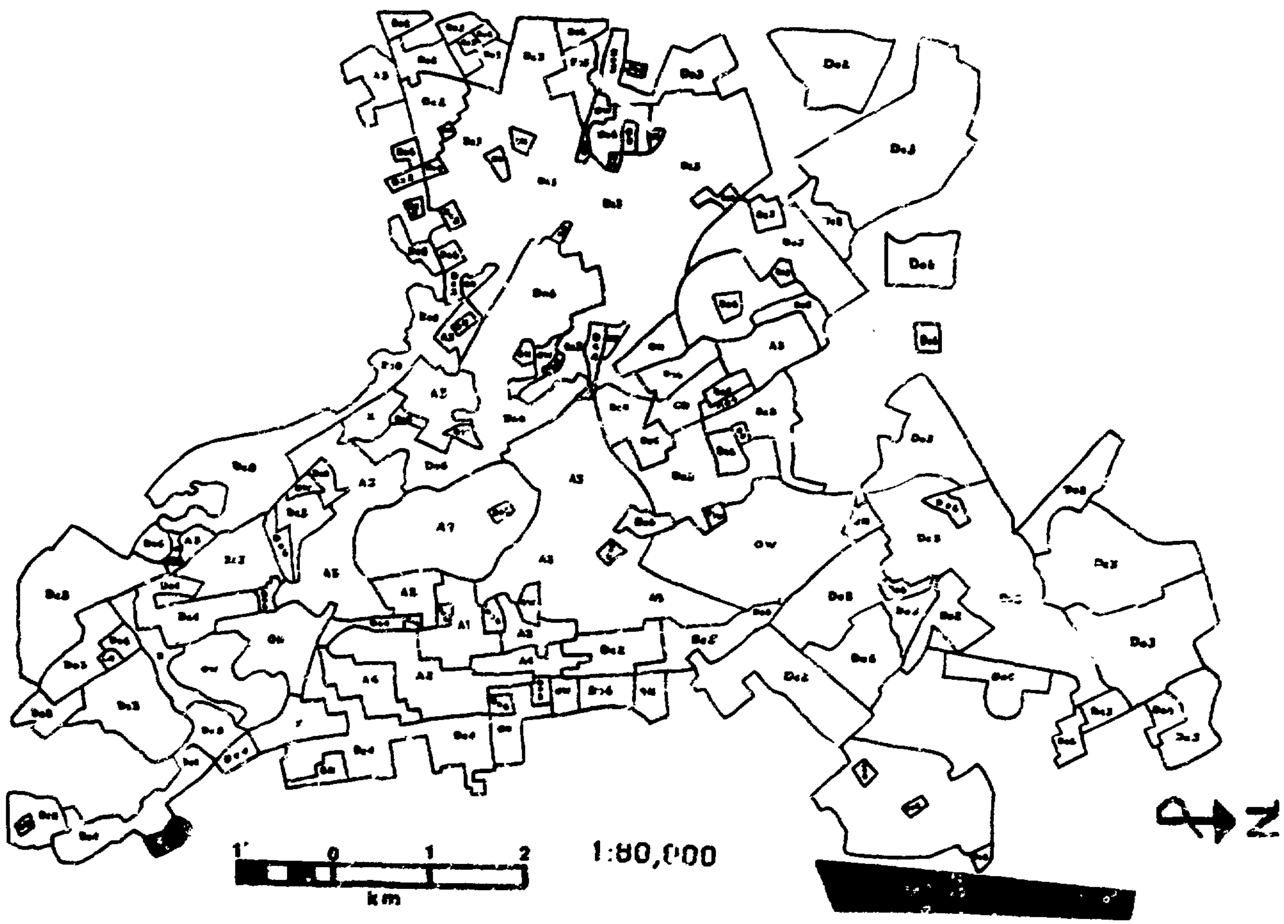
Tunis: Shanty Towns (Dc8)



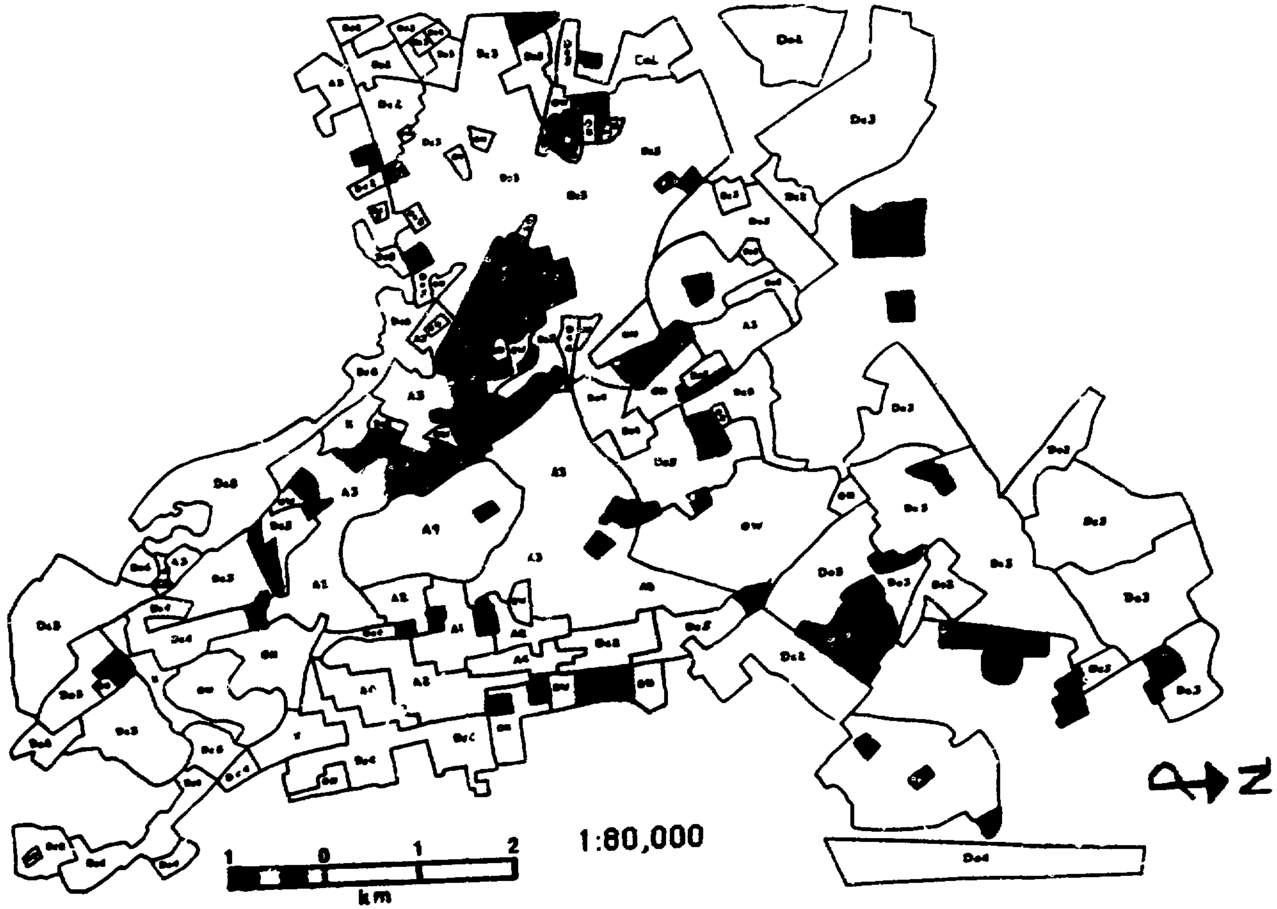
Tunis: Apartments, <75% ground coverage (Do2)



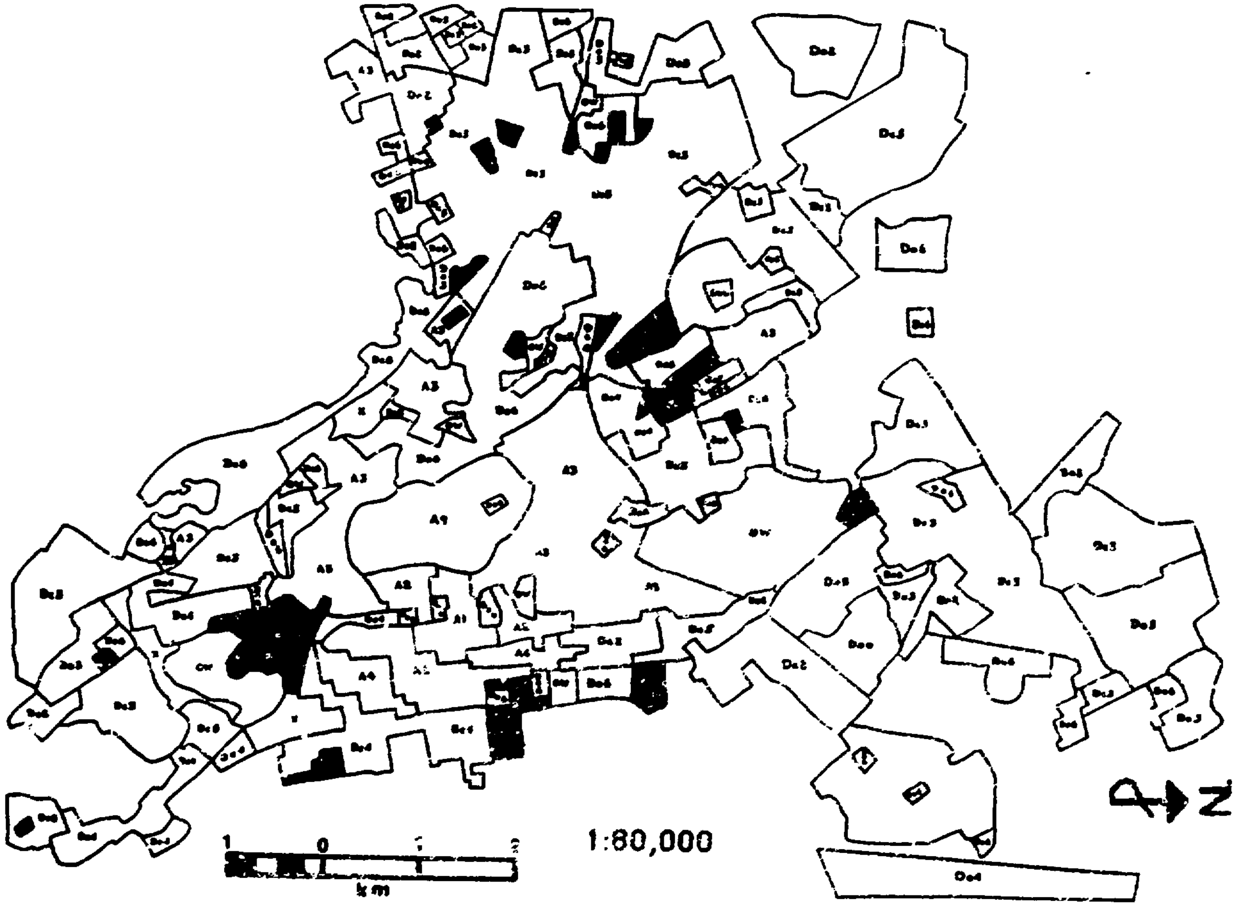
Tunis: Houses, <75% ground coverage (Do3)



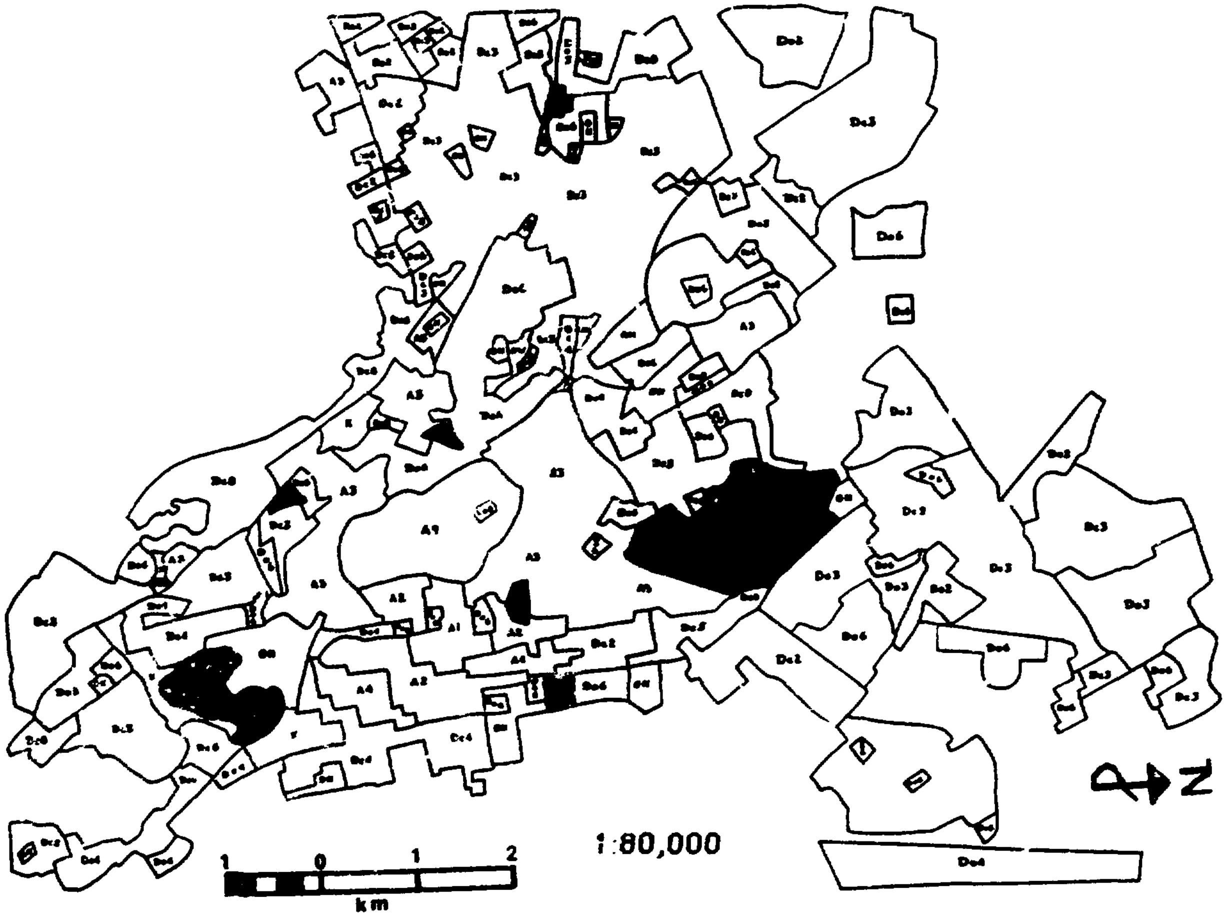
Tunis: Industrial/storage, truck-related (Do4)



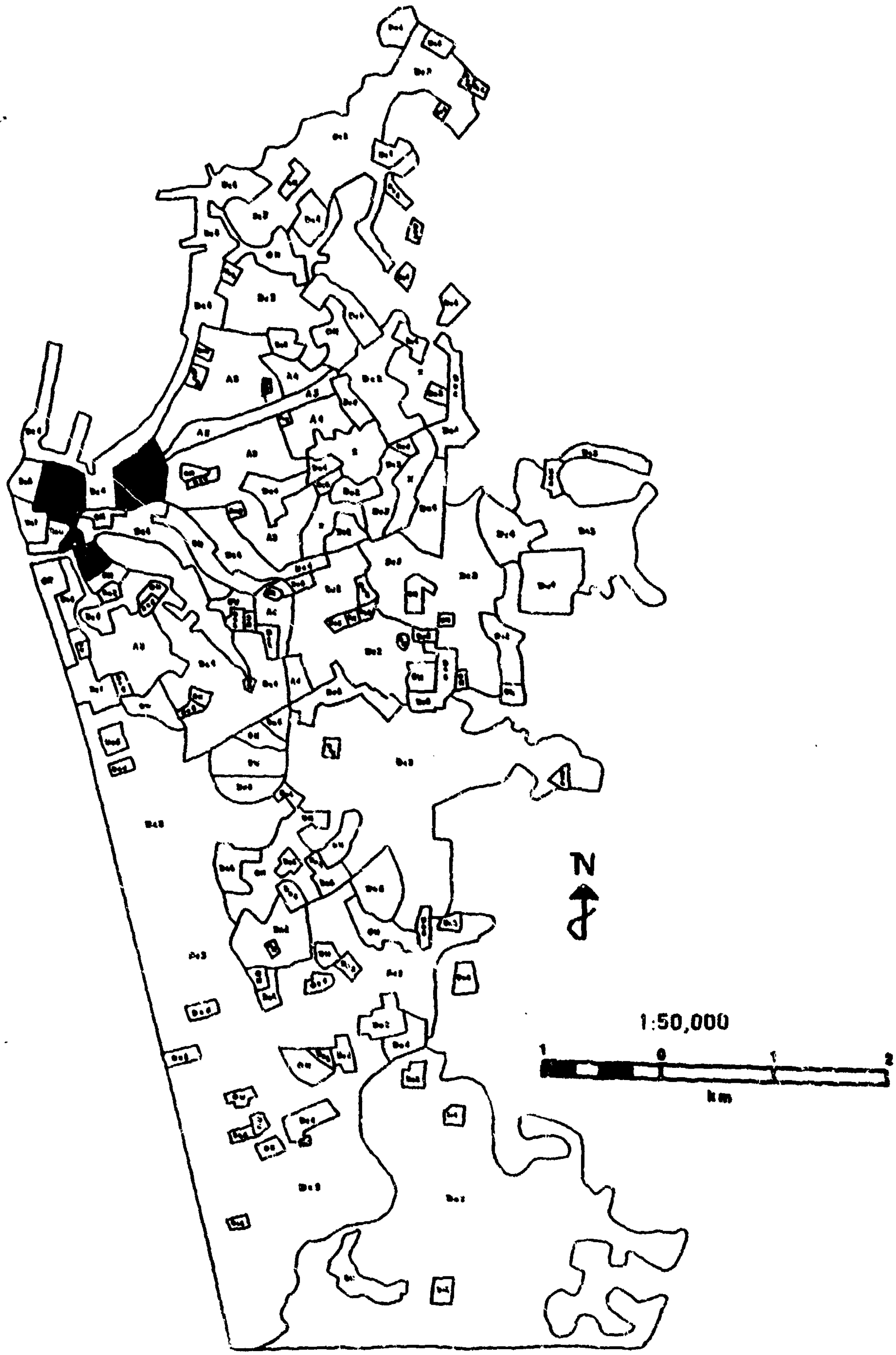
Tunis: Administrative/cultural (Do5)



Tunis: Open Space, not built upon (ON)

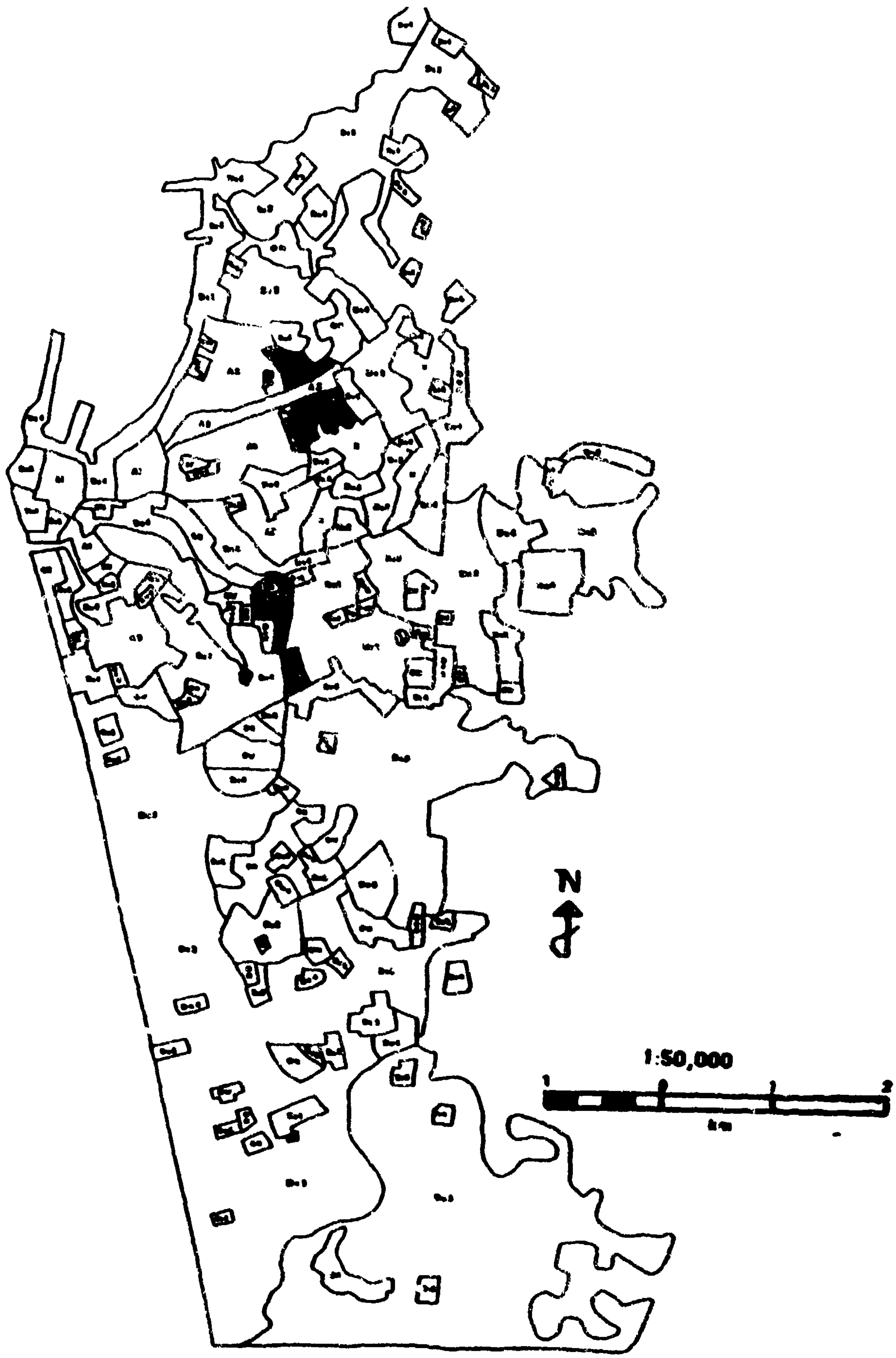


Tunis: Open Space, wooded, not built upon (OW)

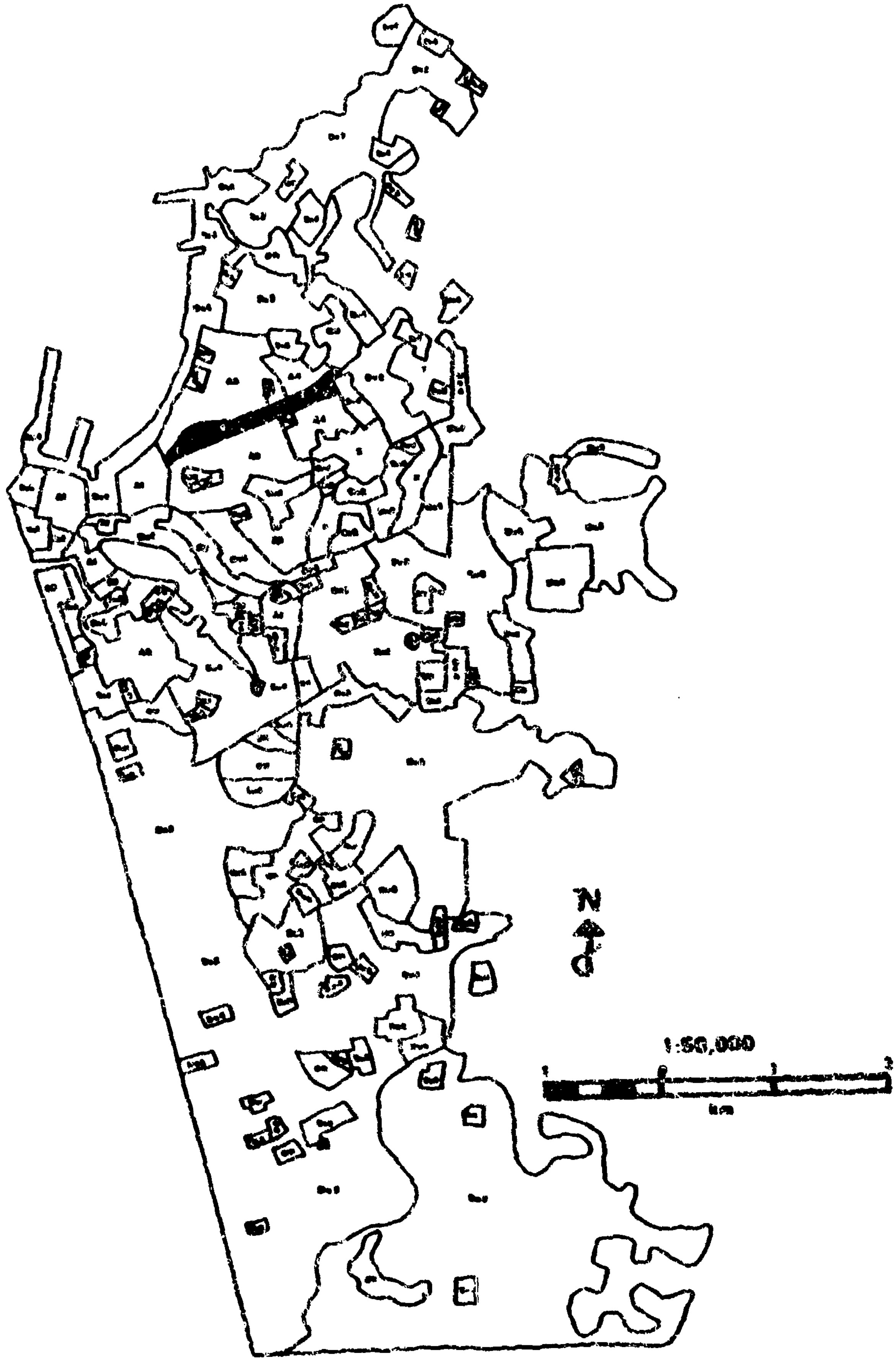


Colombo: Core Area (A1)

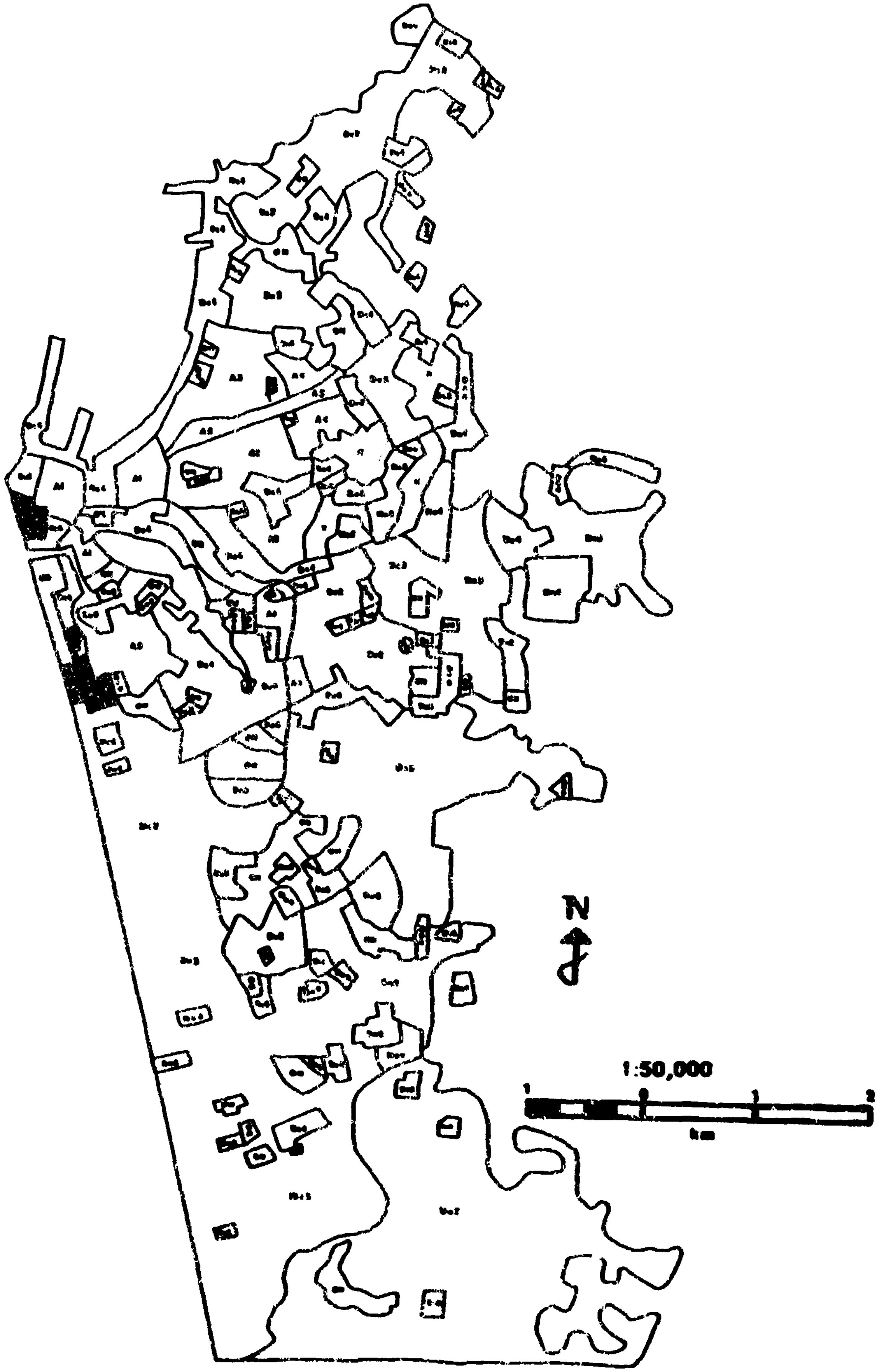
Colombo: Apartments/row houses (A3)



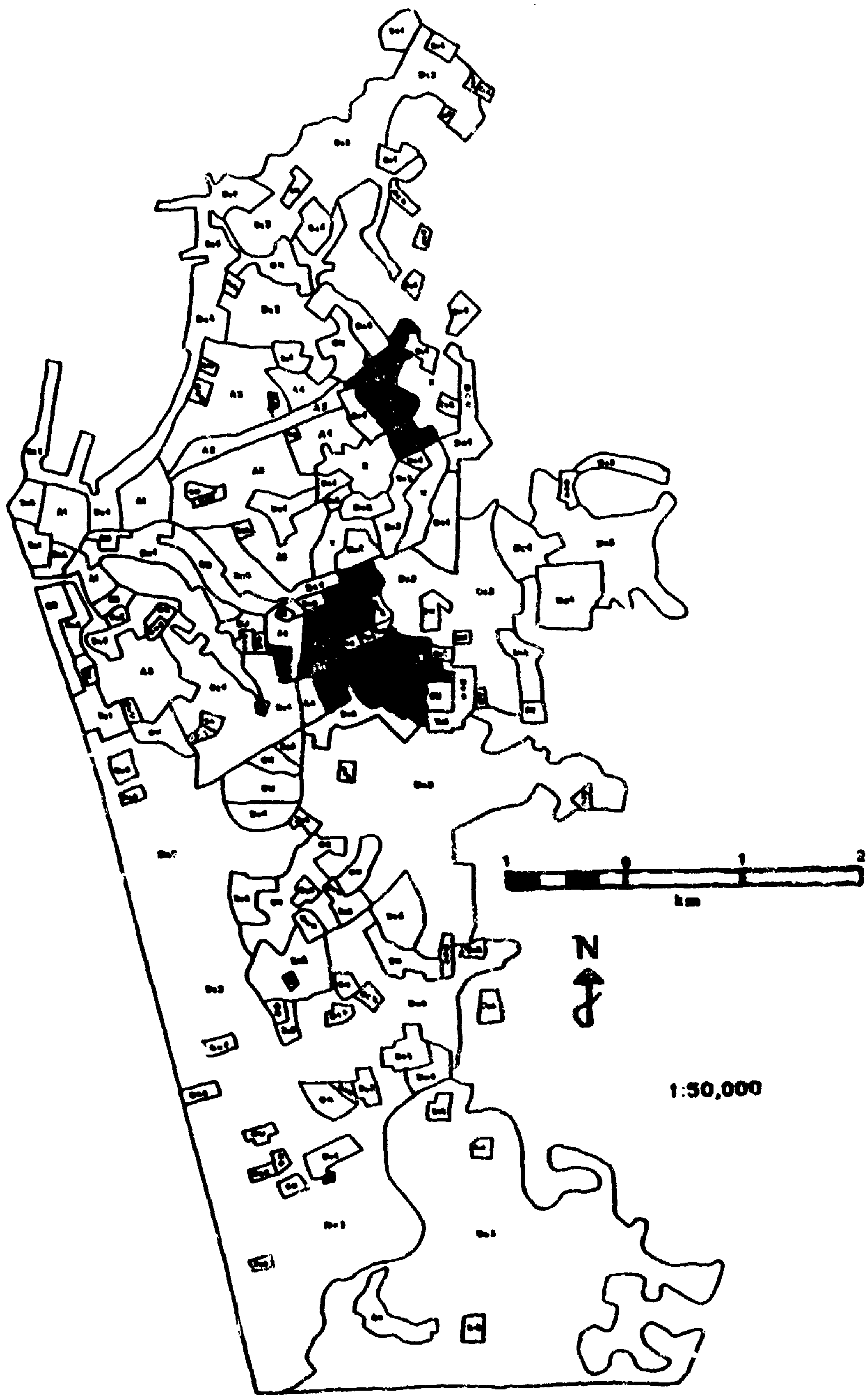
Colombo: Industrial/storage, full urban form (A4)



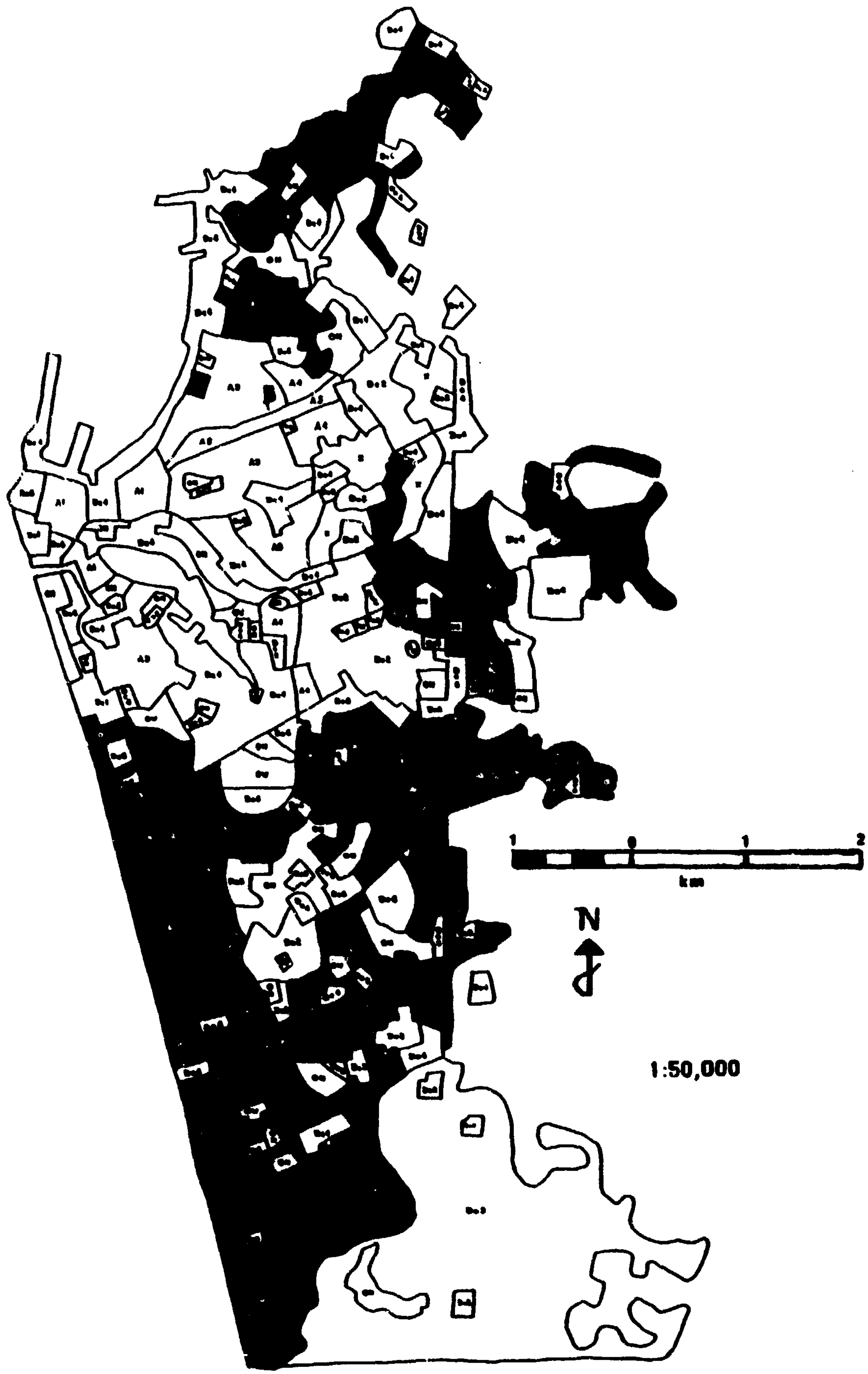
Colombo: Old Commercial Ribbons (A5)



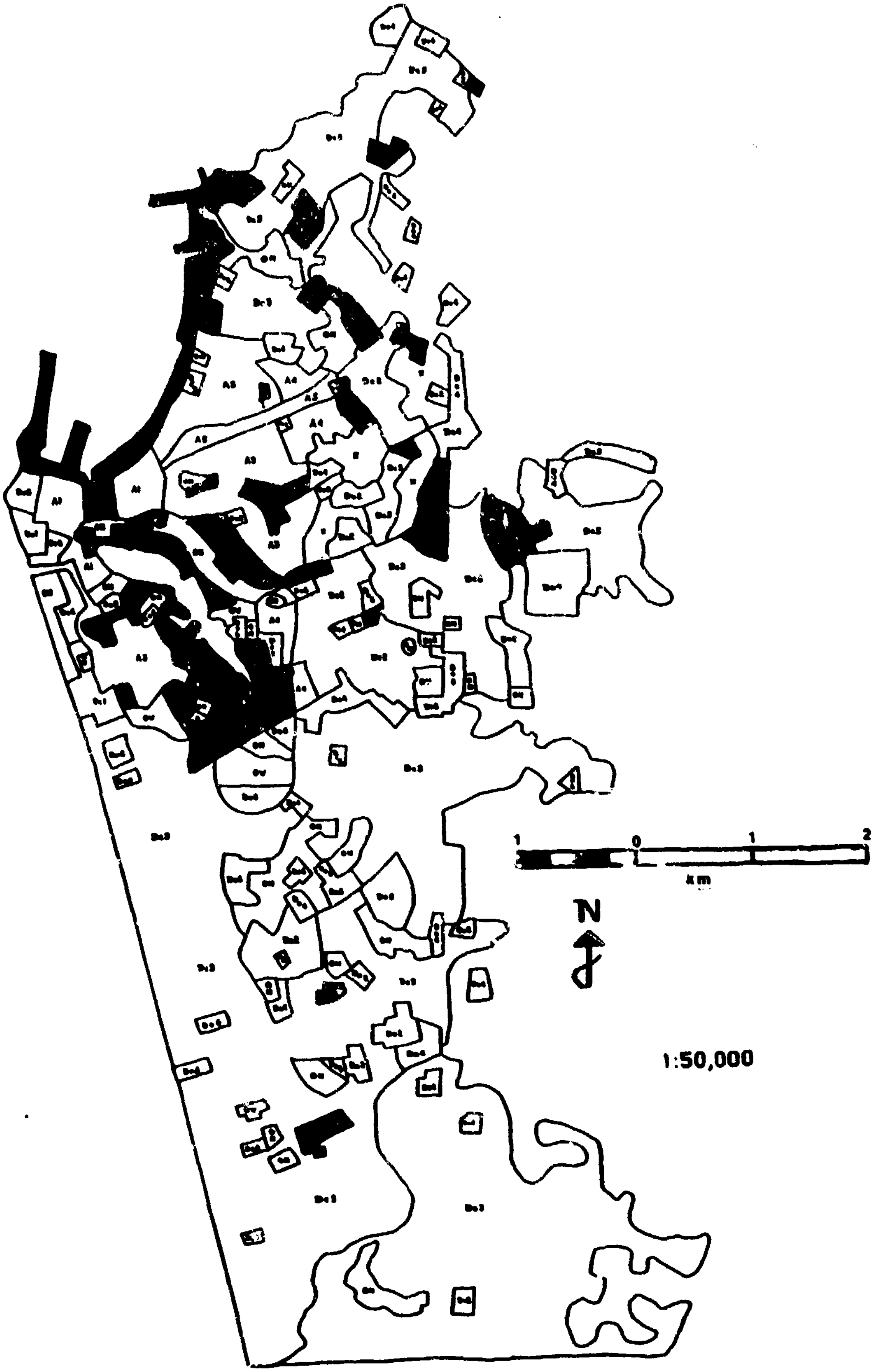
Colombo: Urban Redeveloped core area (Dc1)



Colombo: Apartments, >75% ground coverage (Dc2)

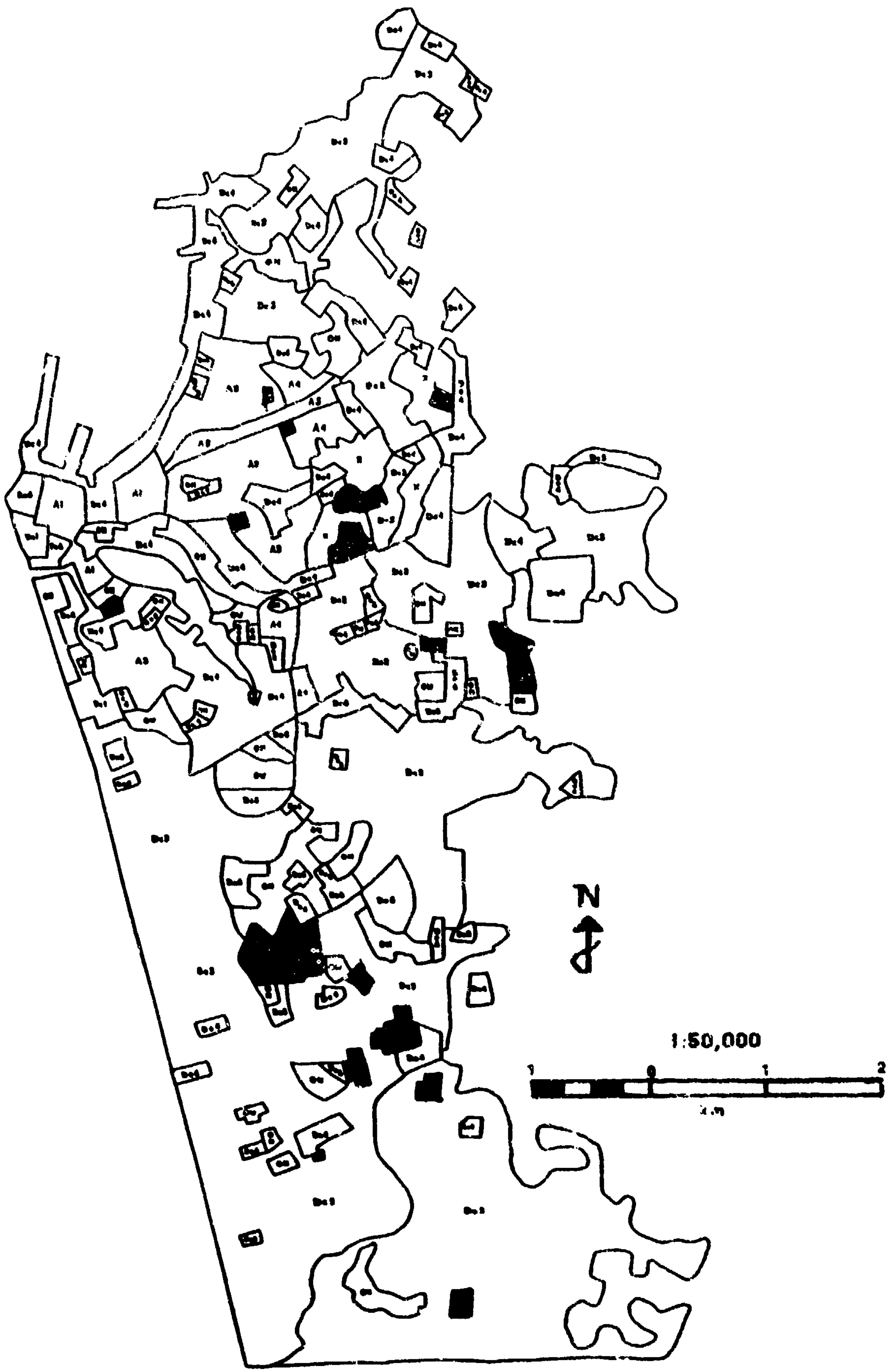


Colombo: Houses, >75% ground coverage (Dc3)

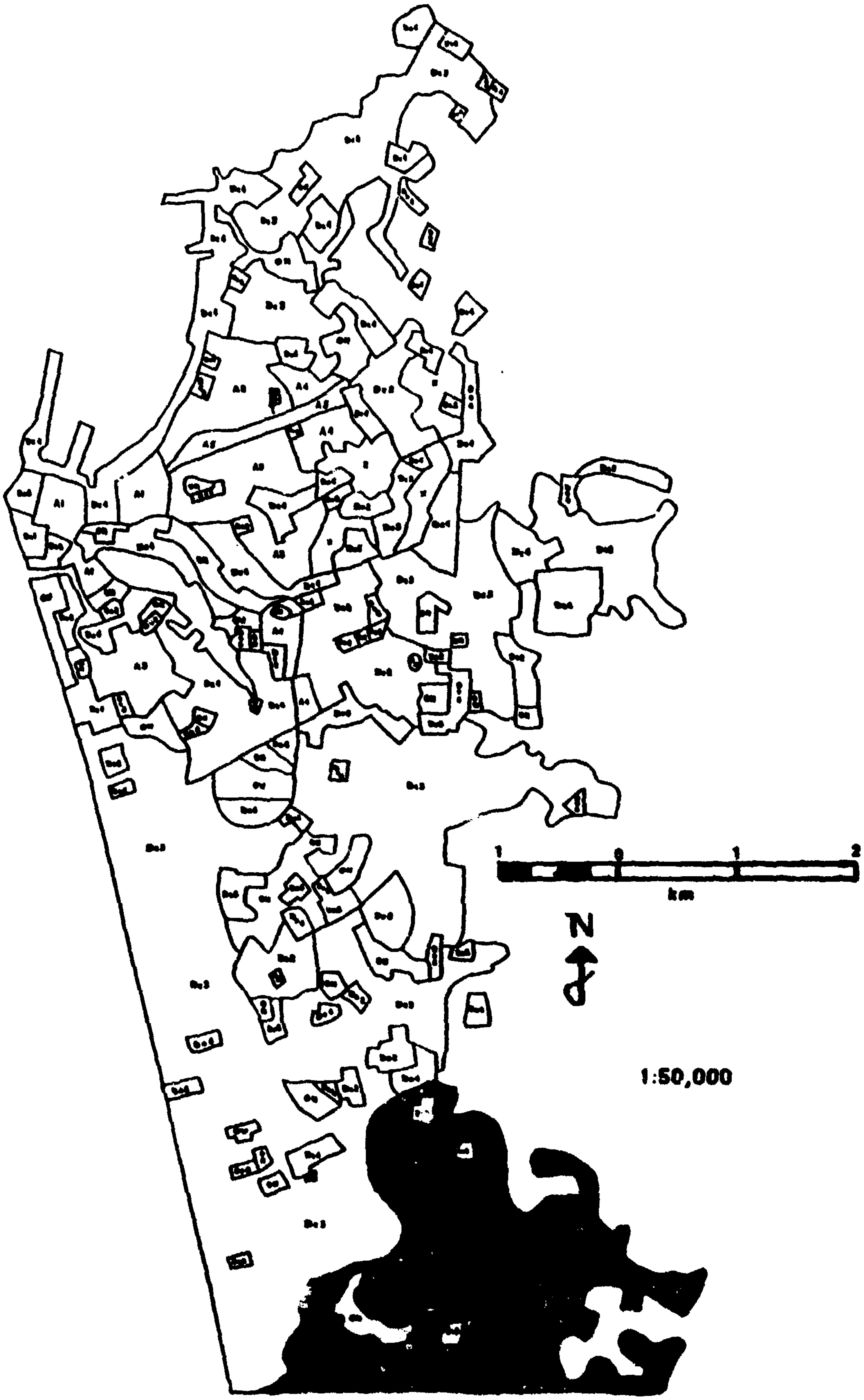


Colombo: Industrial/storage, RR or dock-related (Dc4)

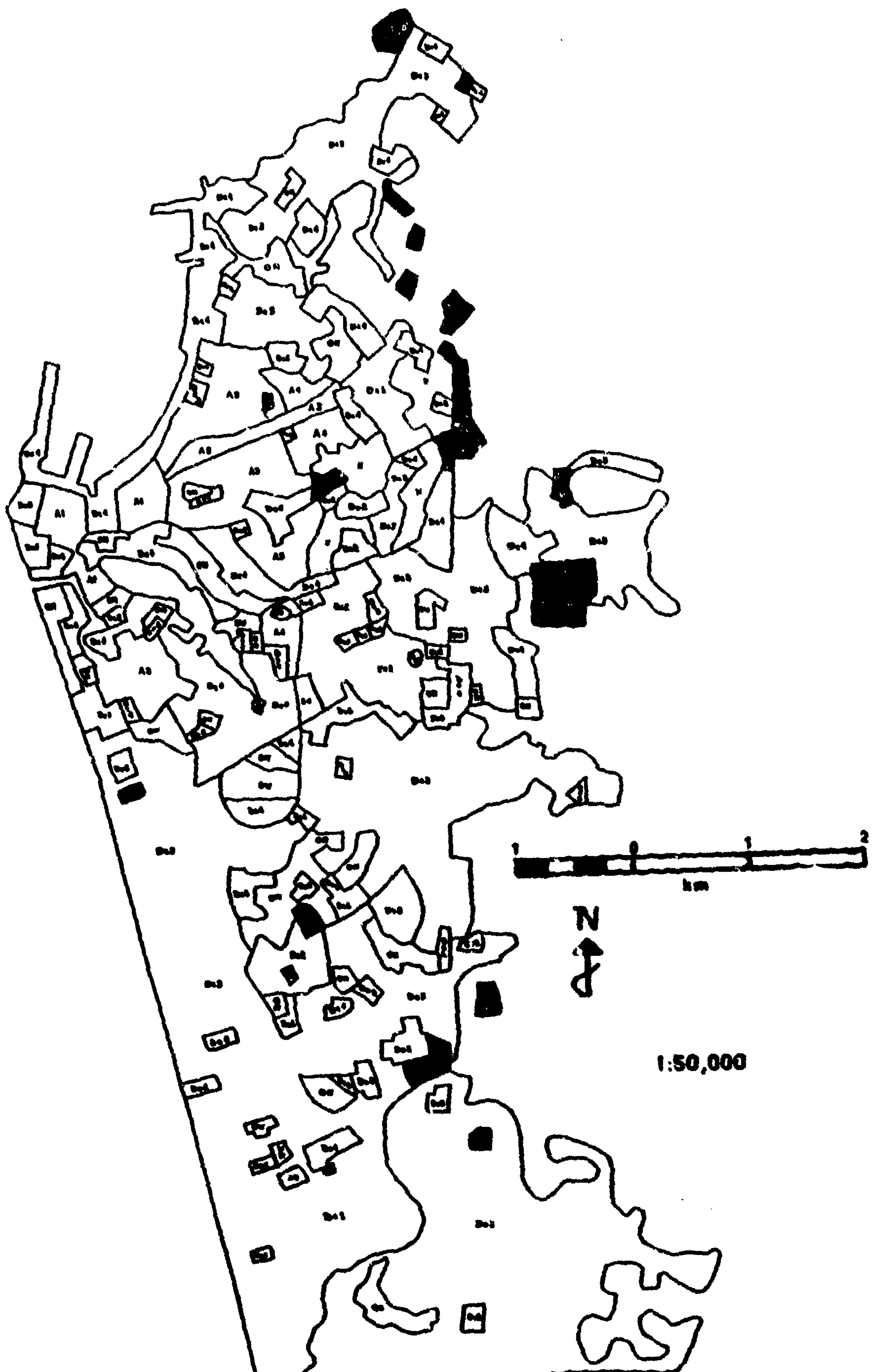
Colombo: Shanty Towns (Dc8)



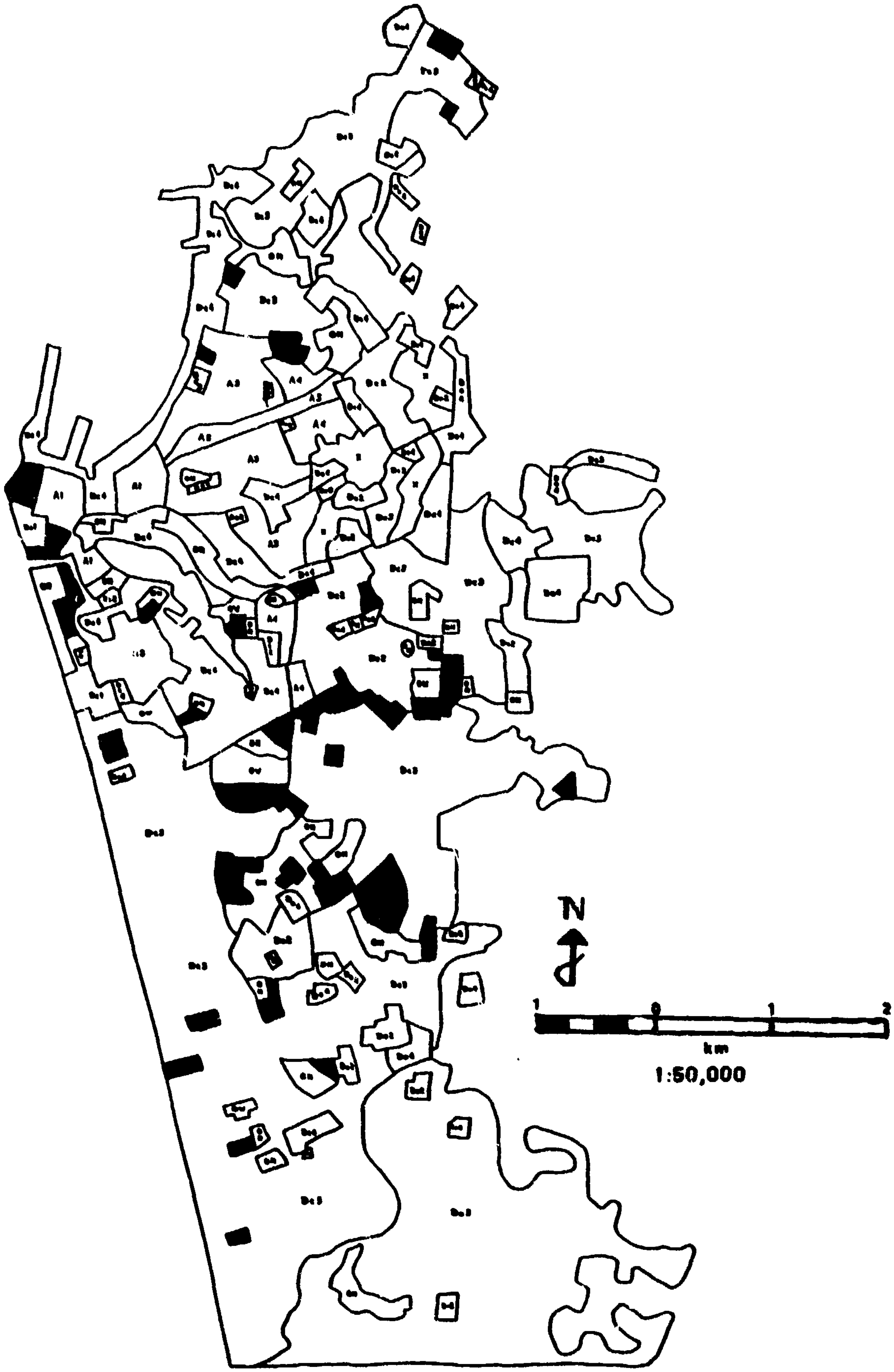
Colombo: Apartments, <75% ground coverage (Do2)



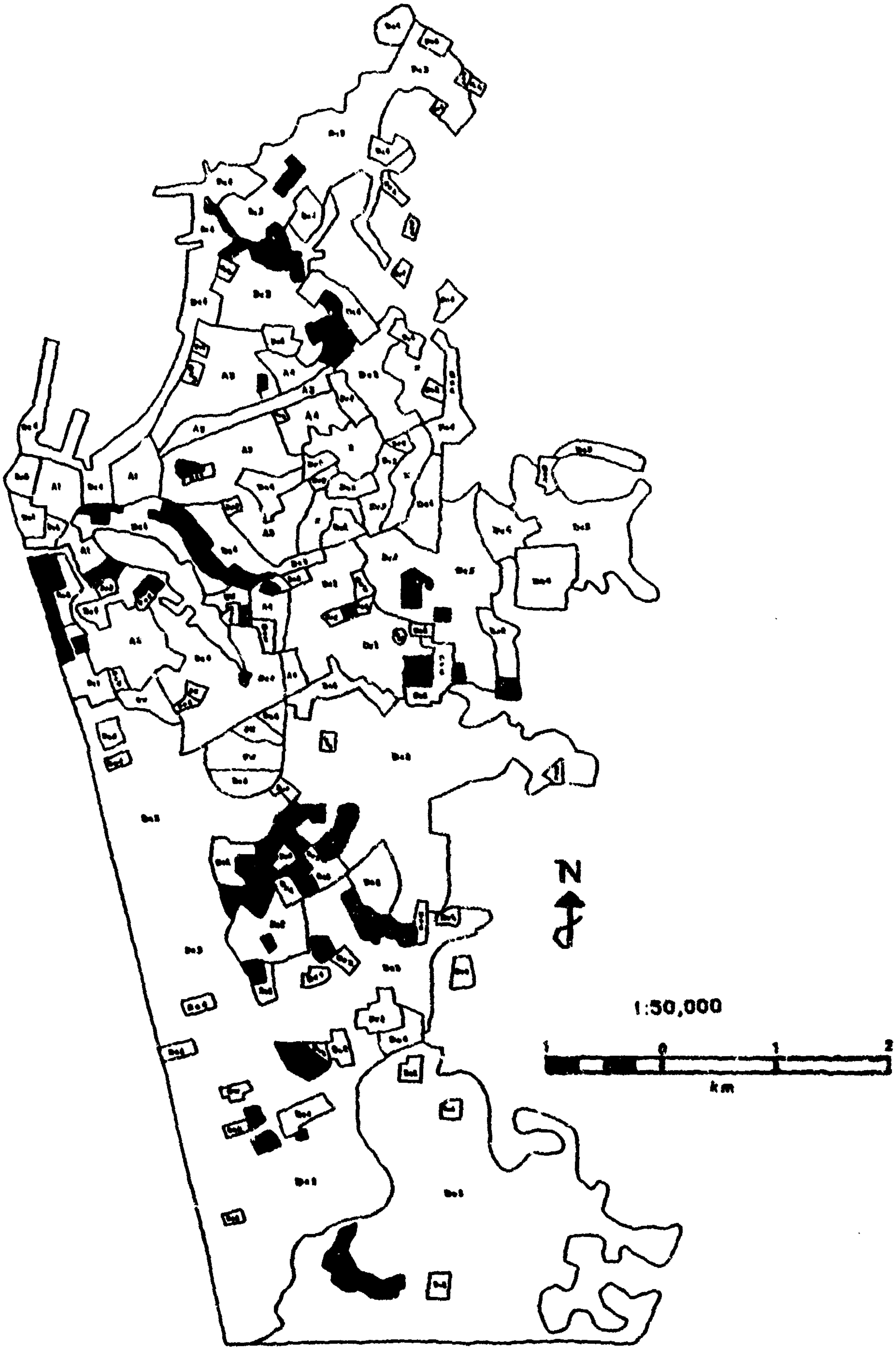
Colombo: Houses, <75% ground coverage (Do3)



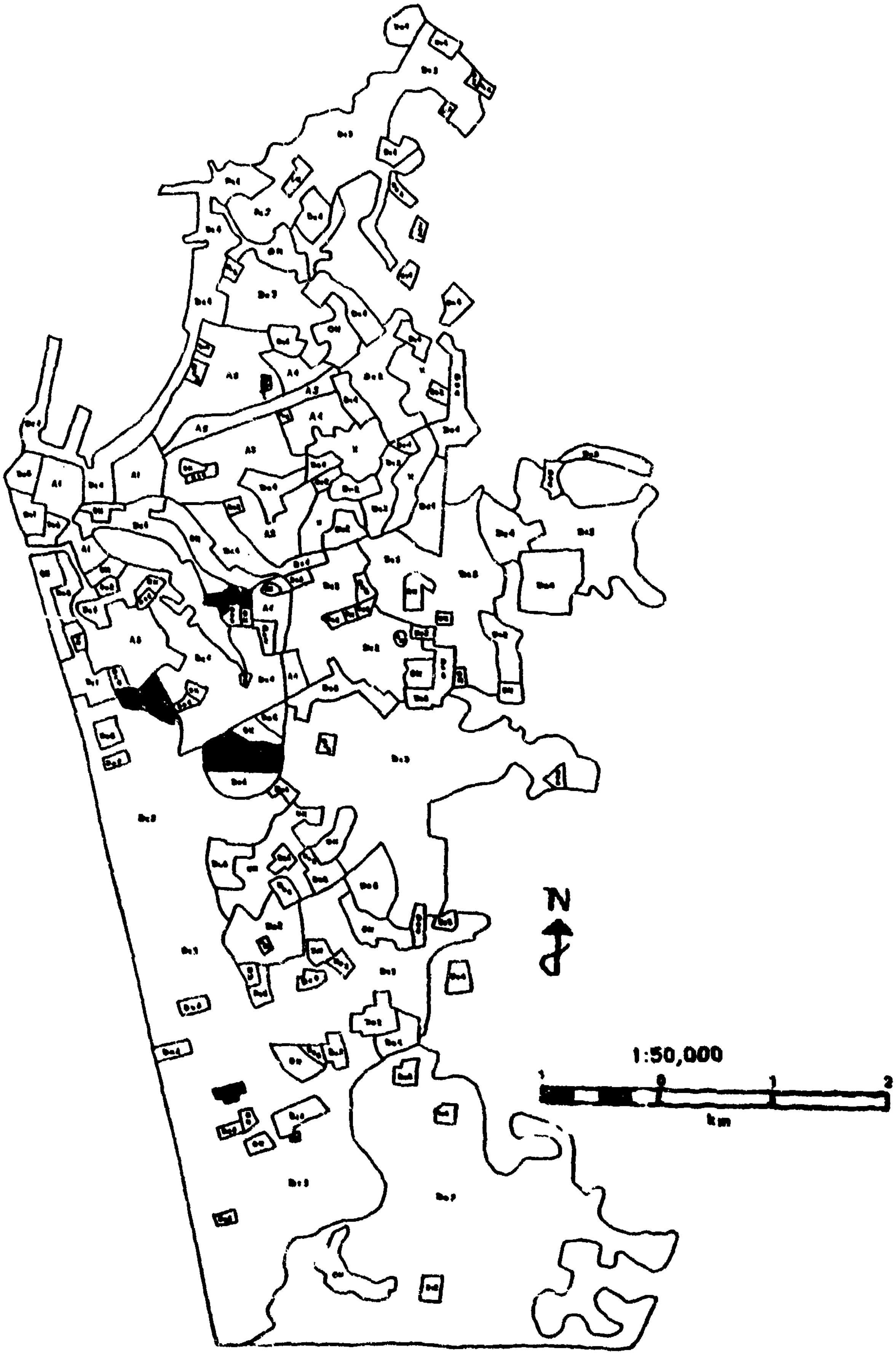
Colombo: Industrial/storage, truck-related (Do4)



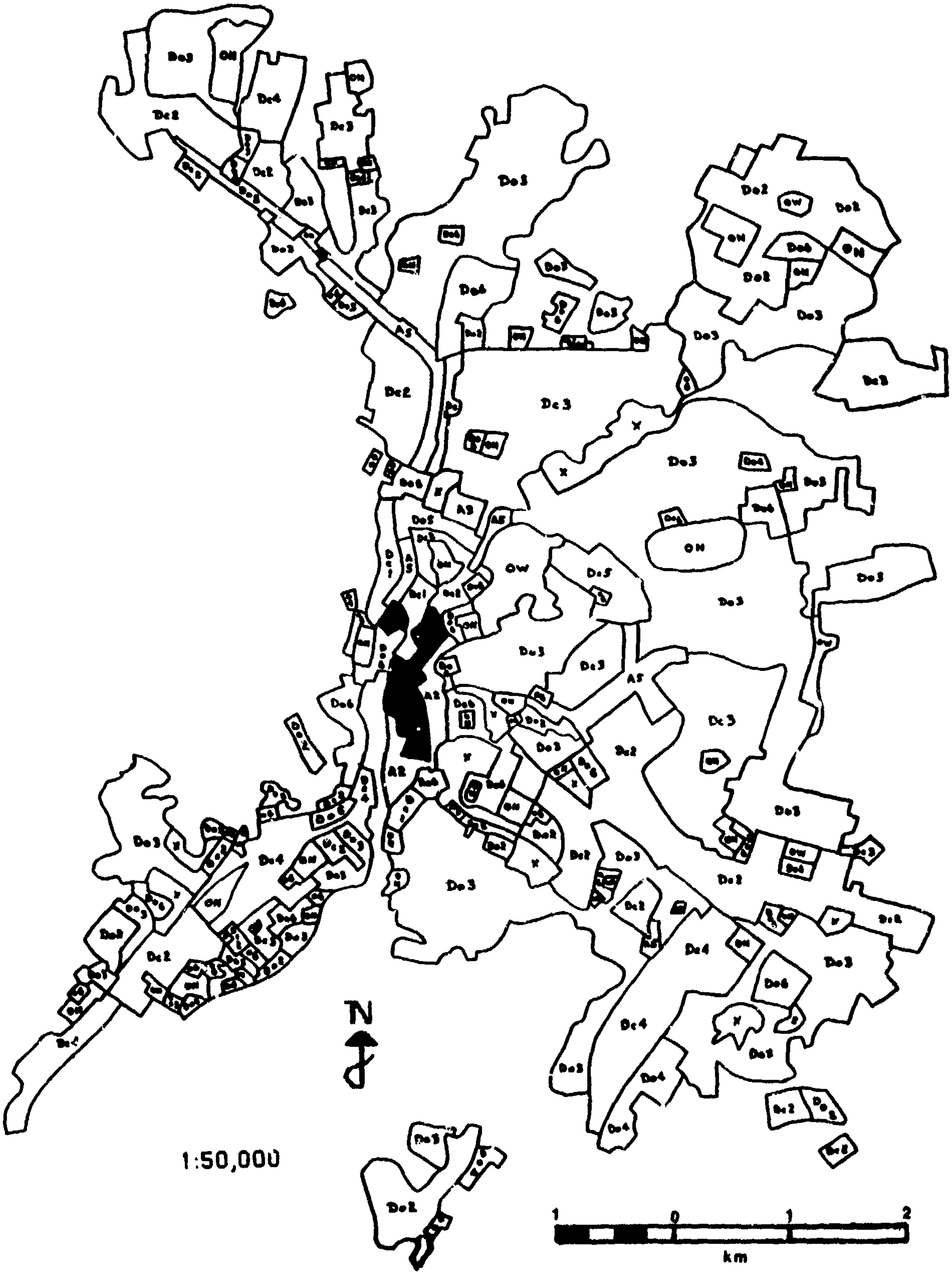
Colombo: Administrative/cultural (Do6)



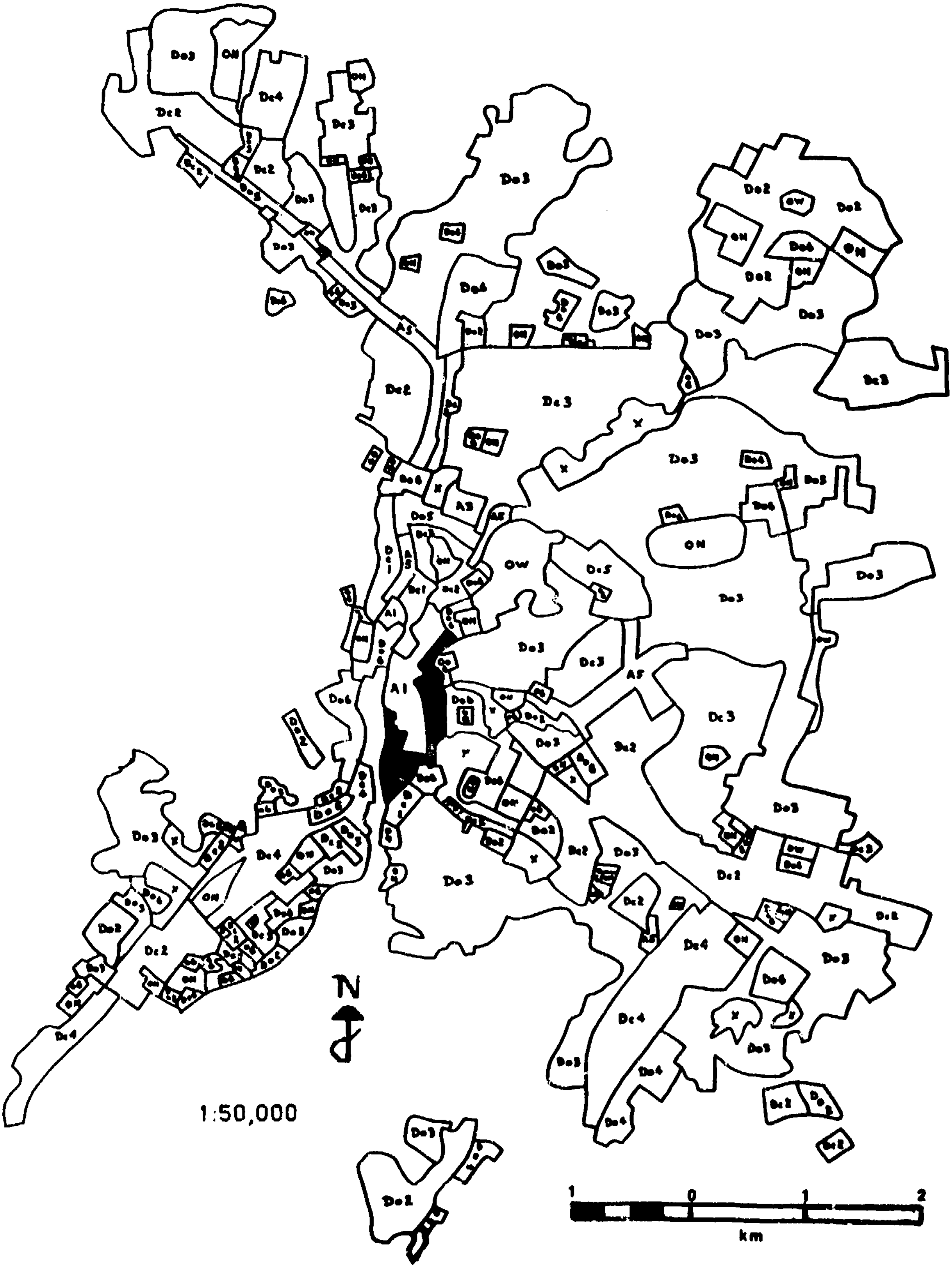
Colombo: Open Space, not built upon (ON)



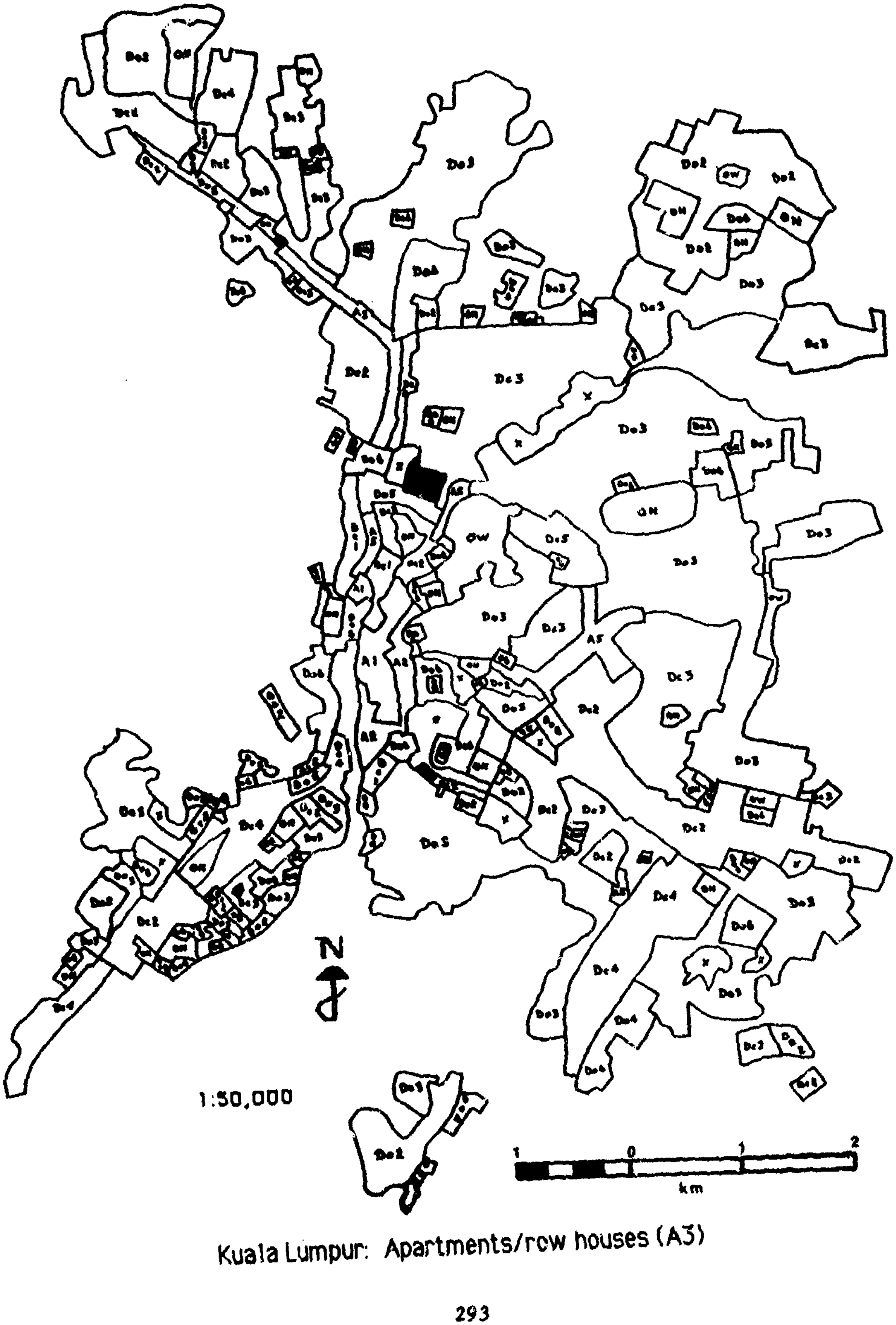
Colombo: Open Space, wooded, not built upon (OW)



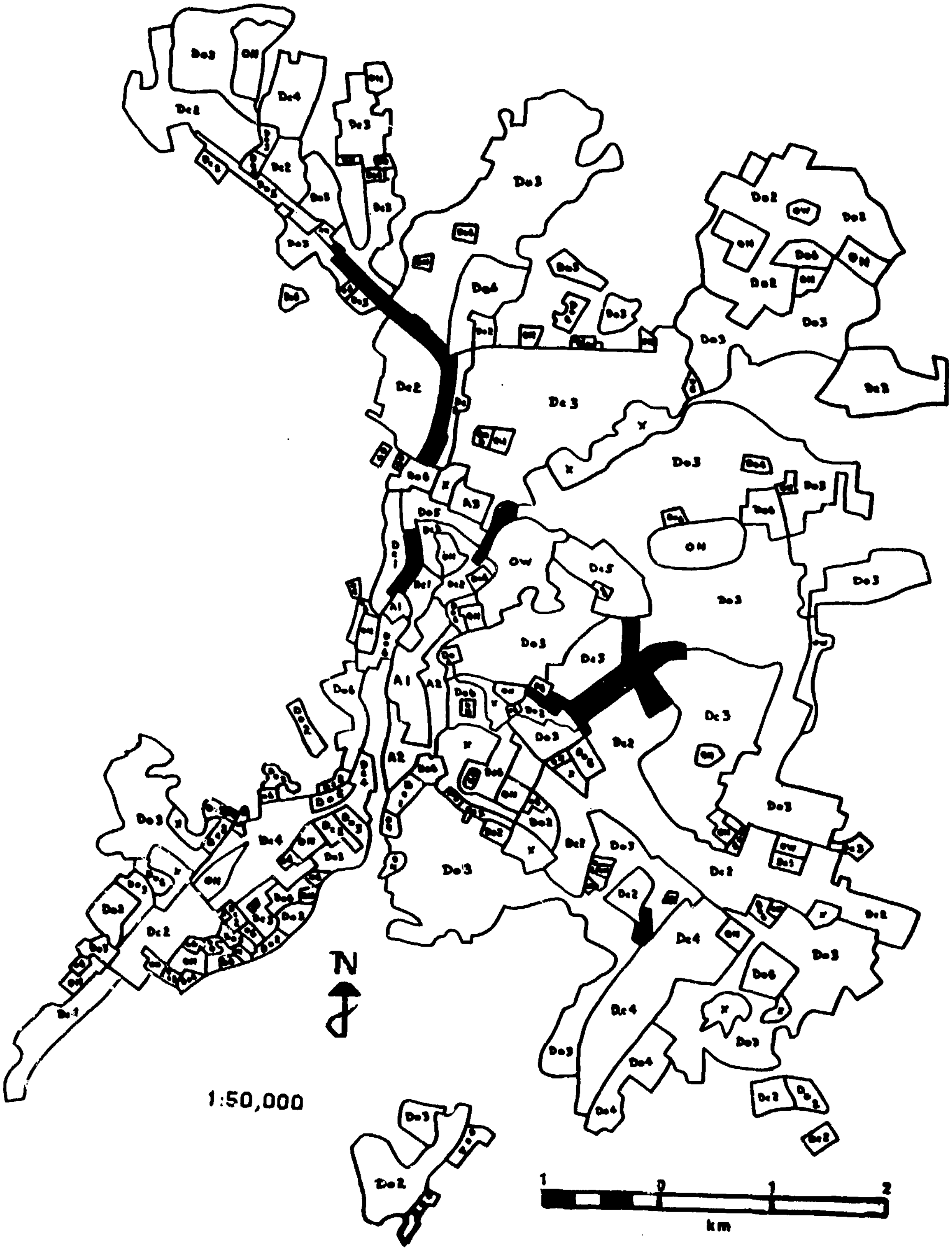
Kuala Lumpur: Core Area (A1)



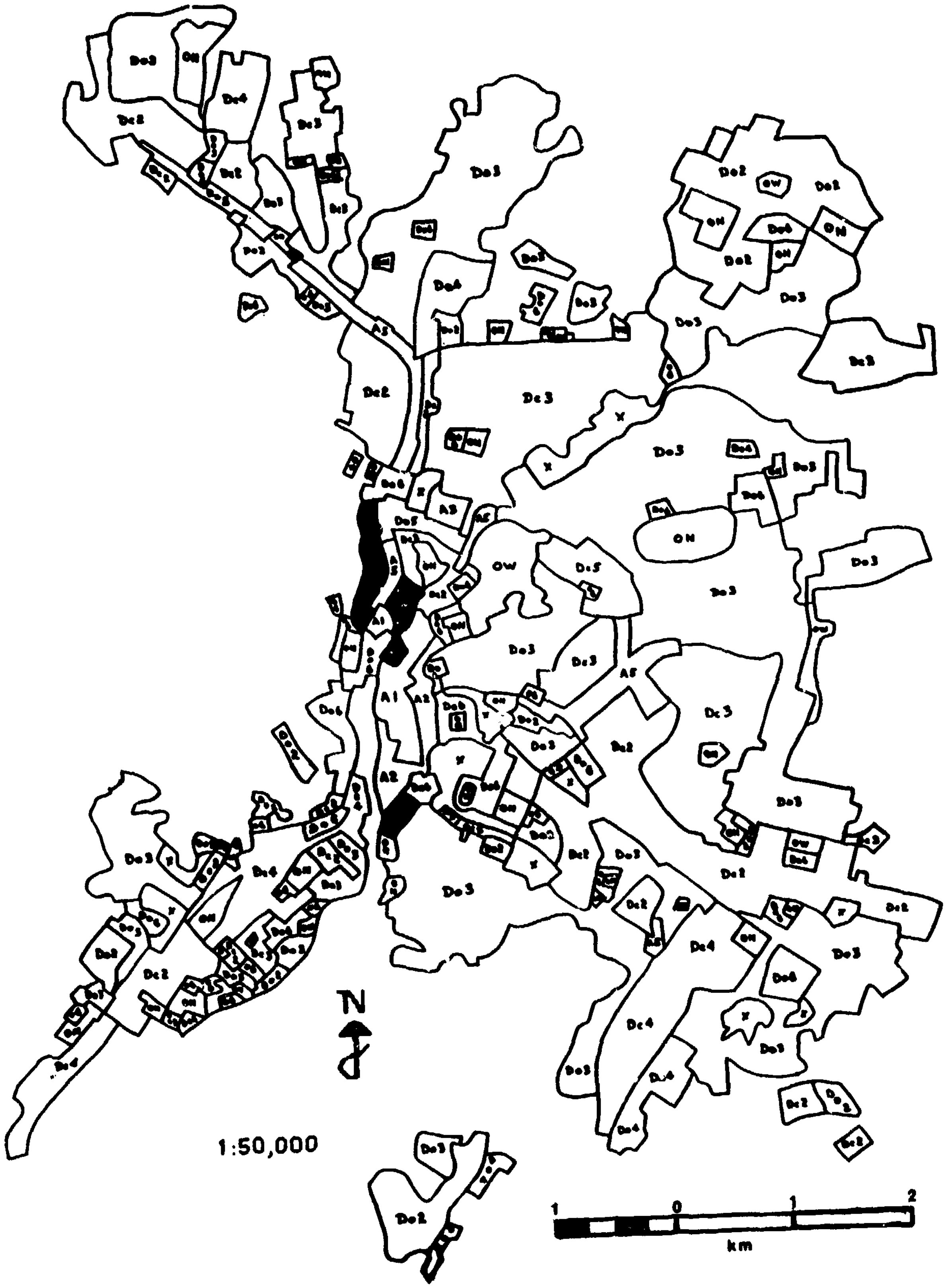
Kuala Lumpur: Apartments/hotels, core periphery (A2)



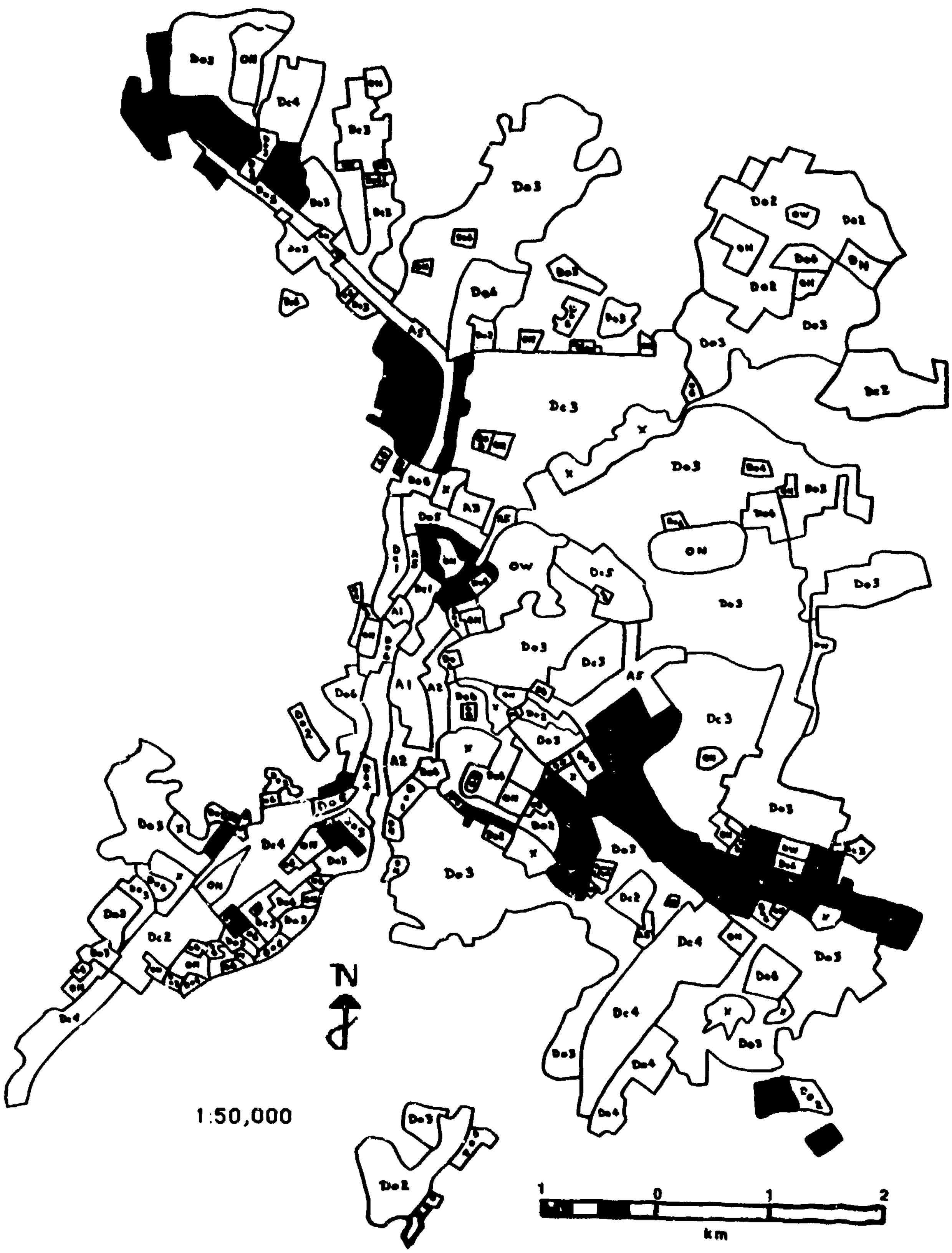
Kuala Lumpur: Apartments/row houses (A3)



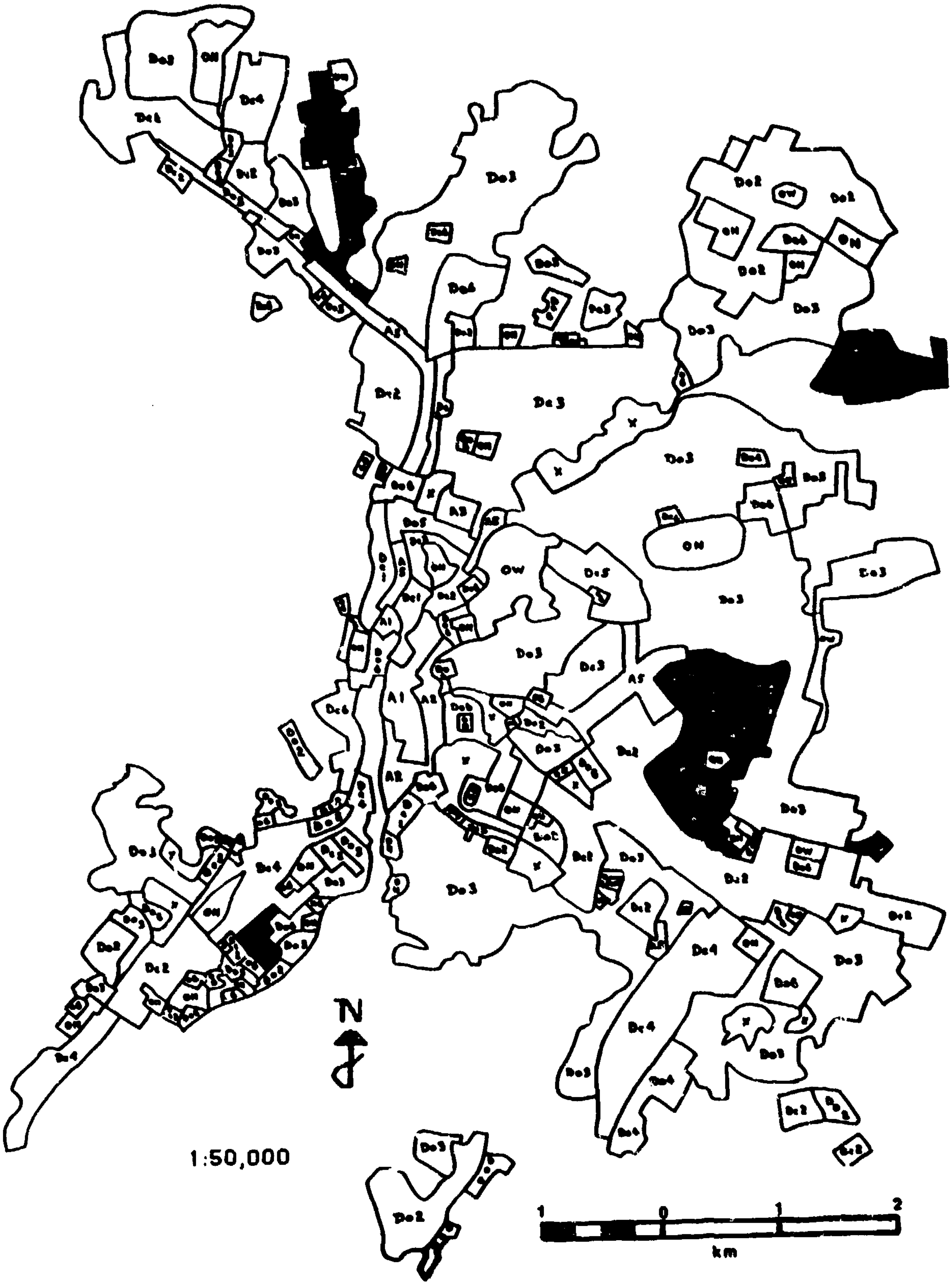
Kuala Lumpur: Old Commercial Ribbons (A5)



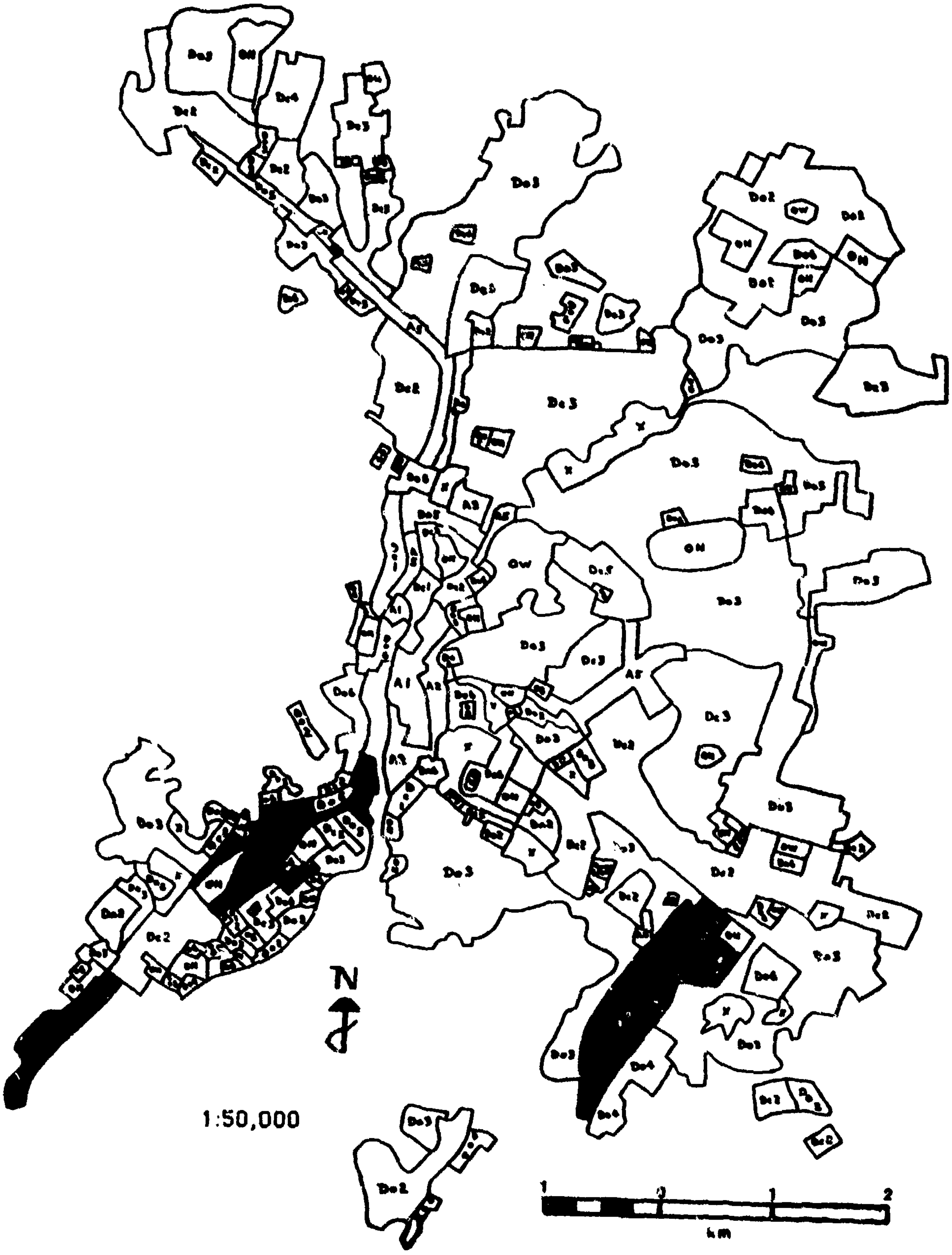
Kuala Lumpur: Urban Redeveloped core area (Dc1)



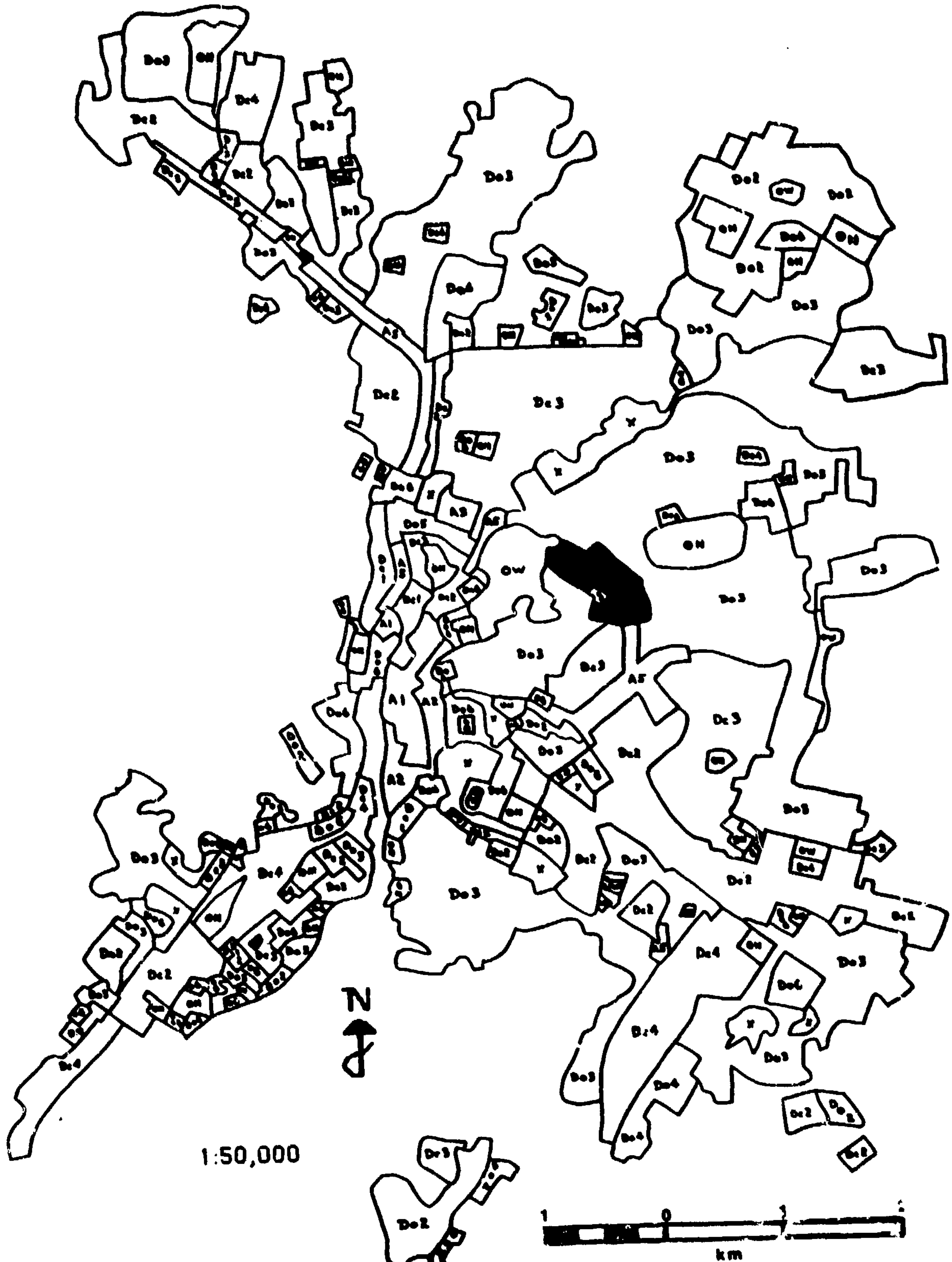
Kuala Lumpur: Apartments, >75% ground coverage (Dc2)



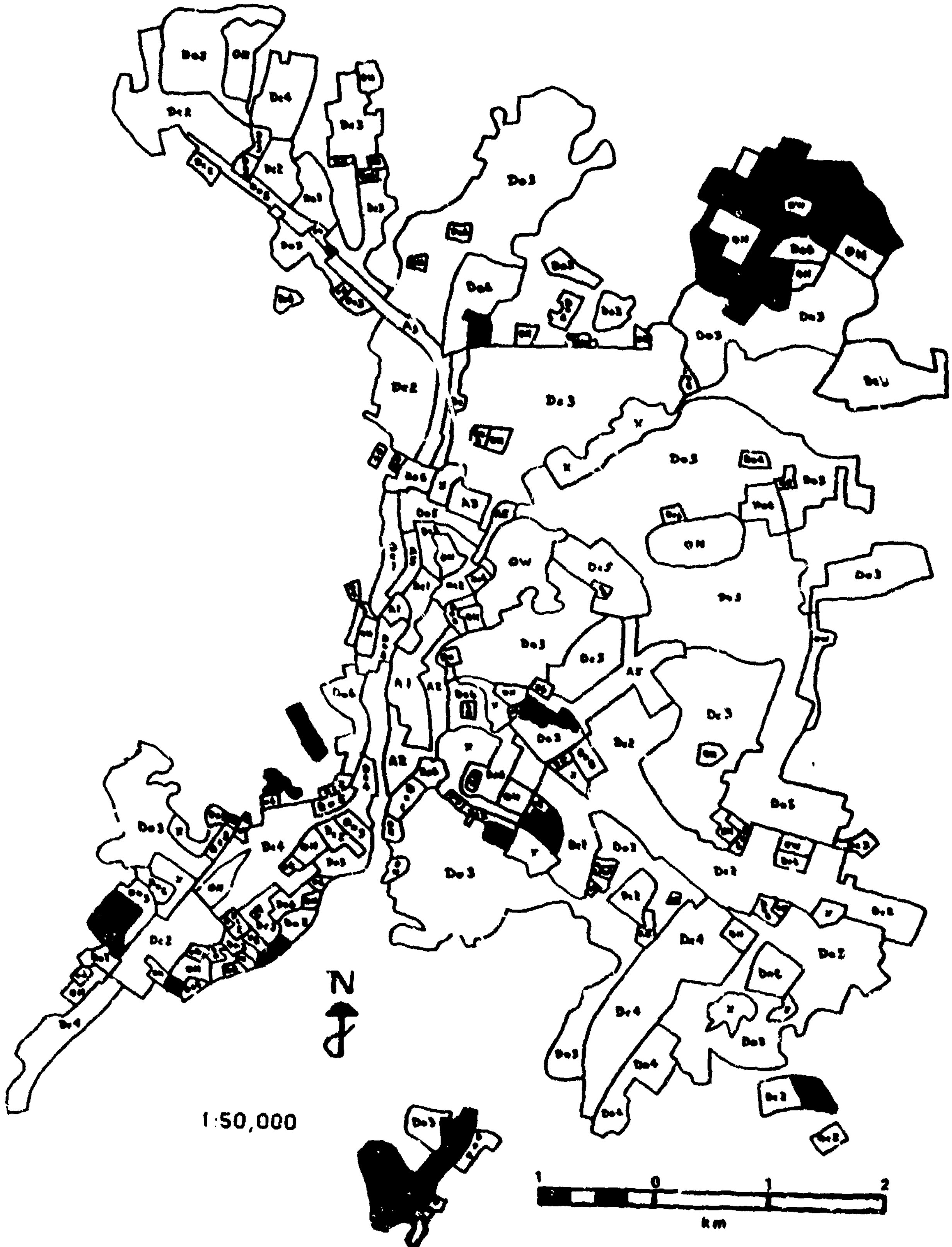
Kuala Lumpur: Houses, >75% ground coverage (Dc3)



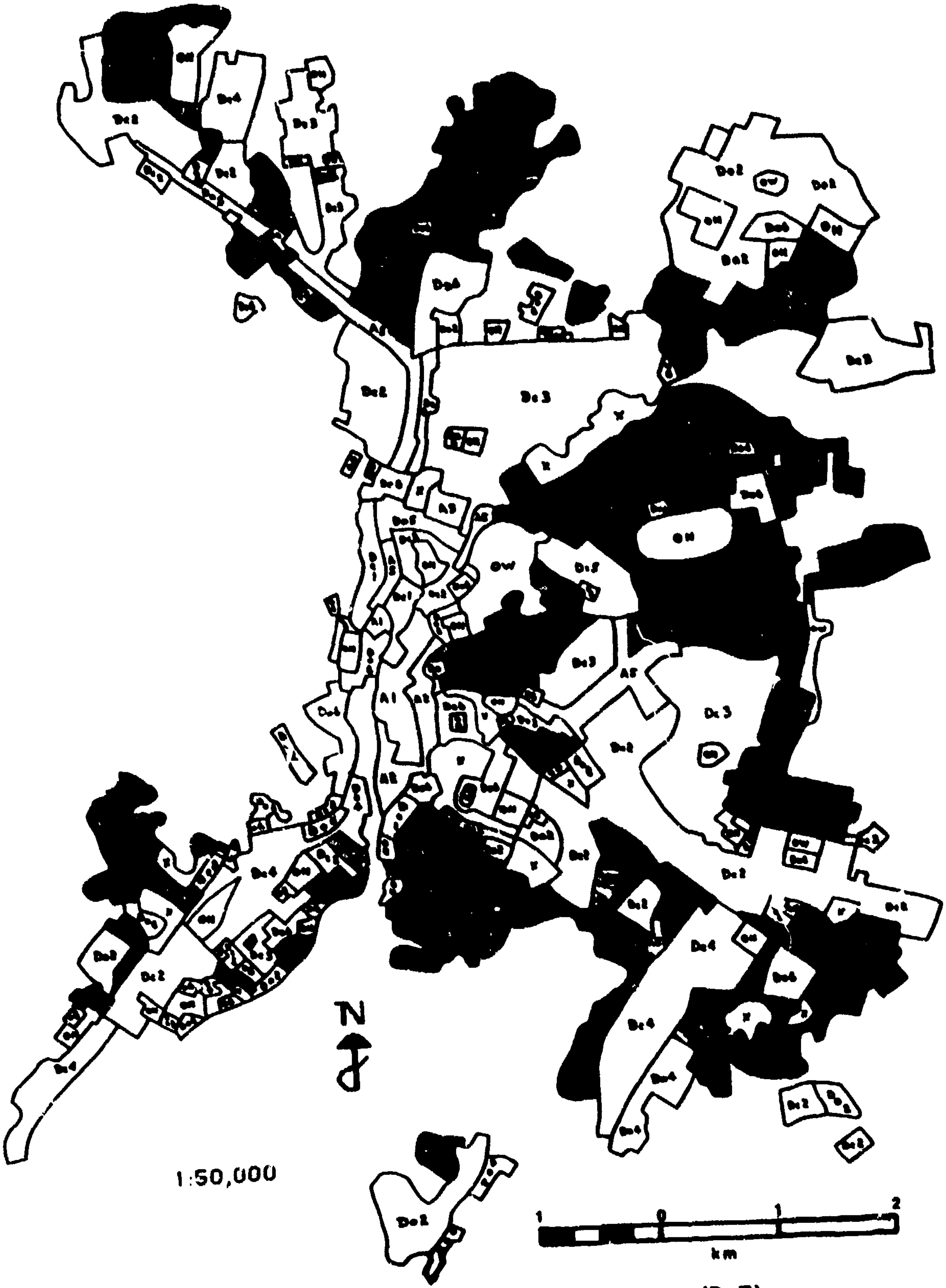
Kuala Lumpur: Industrial/storage, RR or dock-related (Dc4)



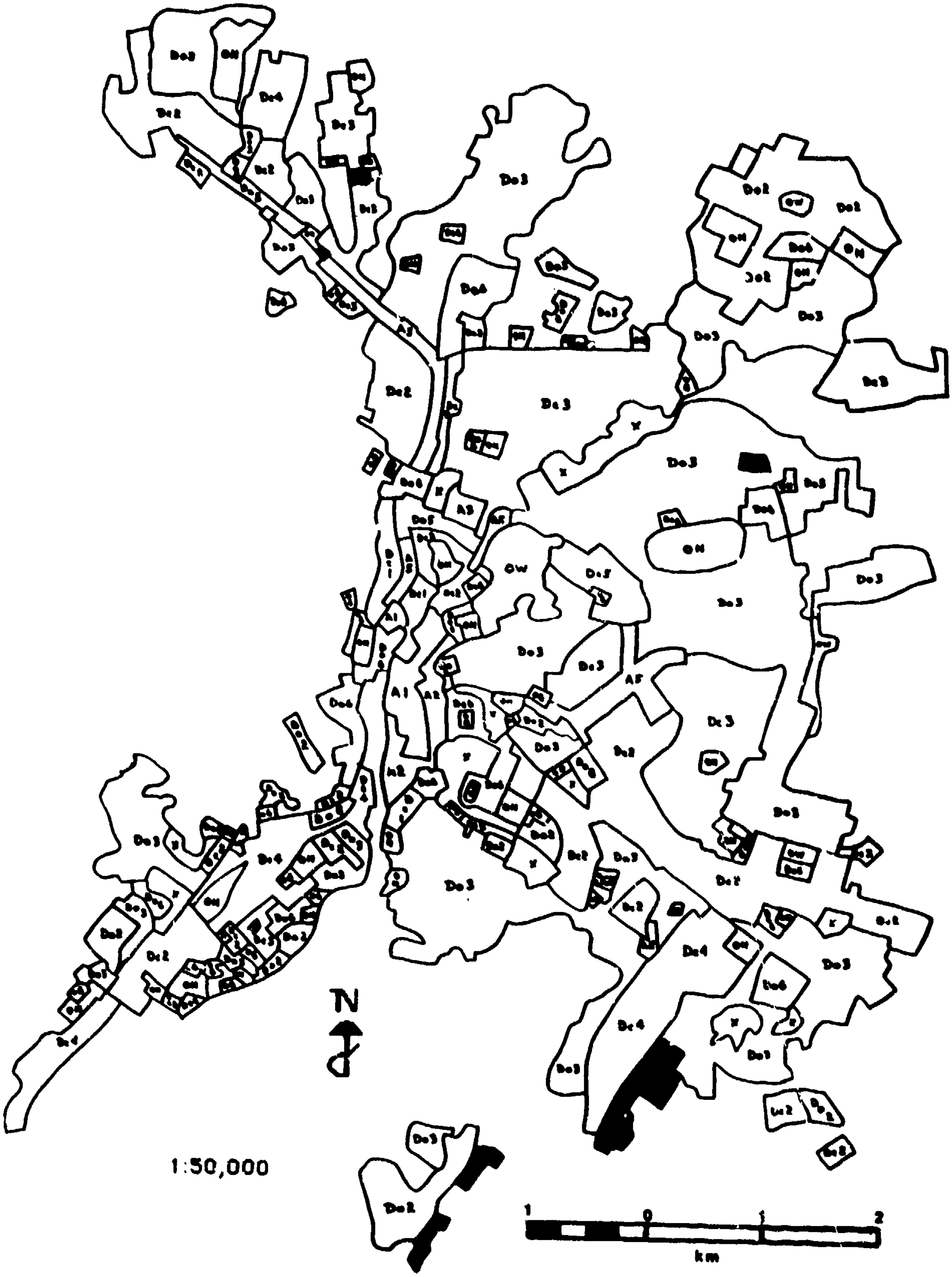
Kuala Lumpur: Outer City (Dc5)



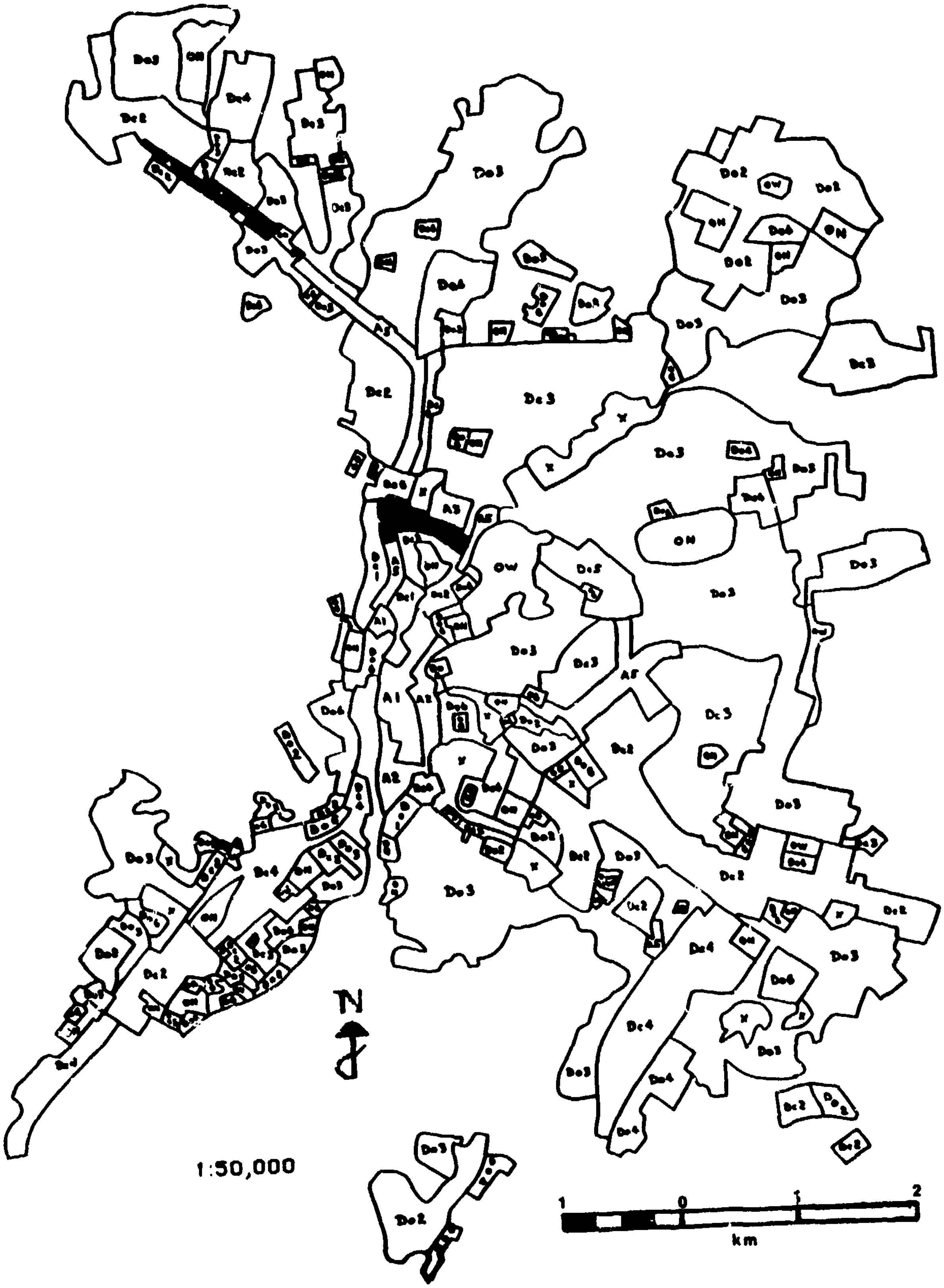
Kuala Lumpur: Apartments, <75% ground coverage (Do2)



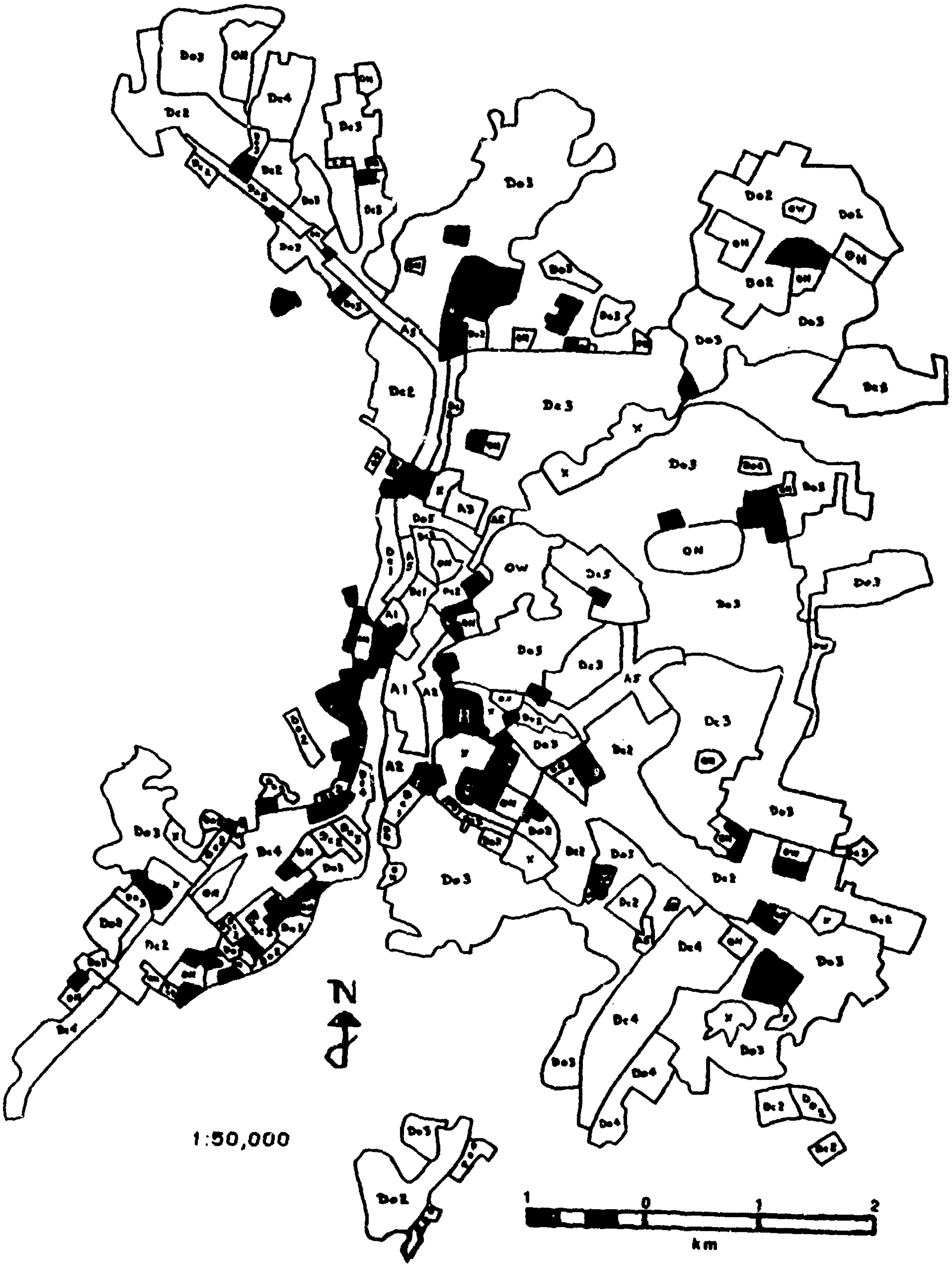
Kuala Lumpur: Houses, <75% ground coverage (Do3)



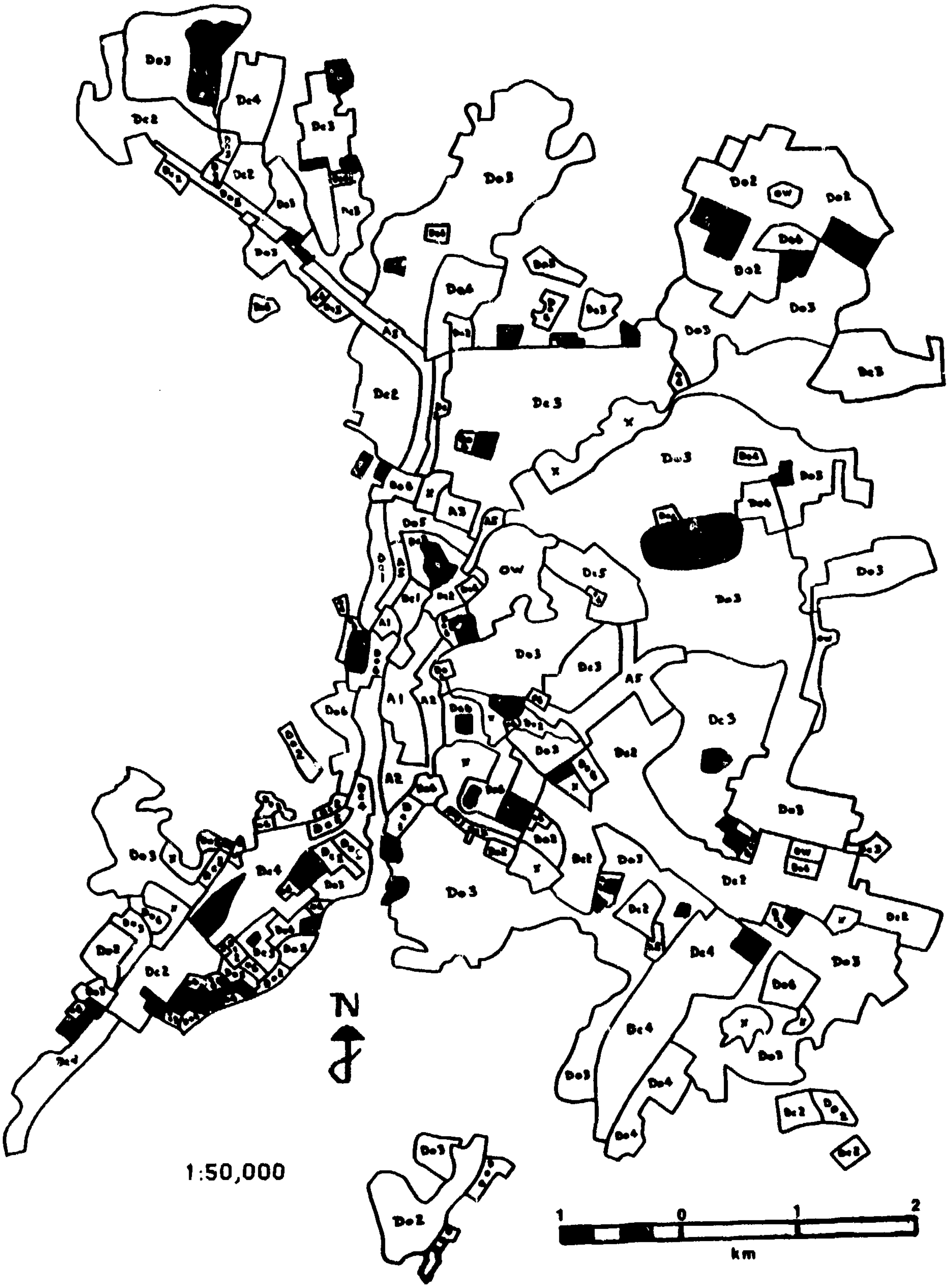
Kuala Lumpur: Industrial/storage, truck-related (Do4)



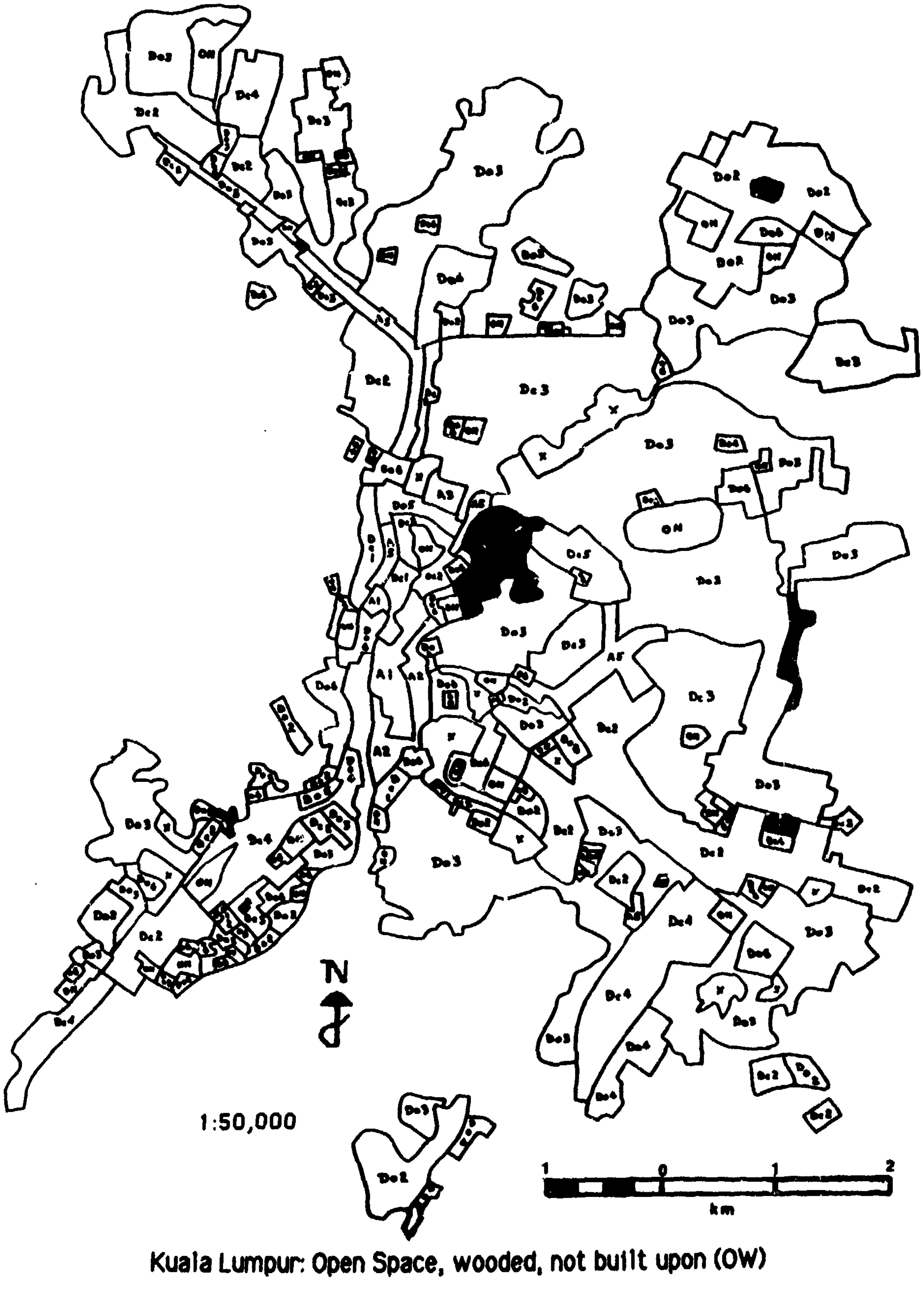
Kuala Lumpur: New Commercial Ribbons (Do5)



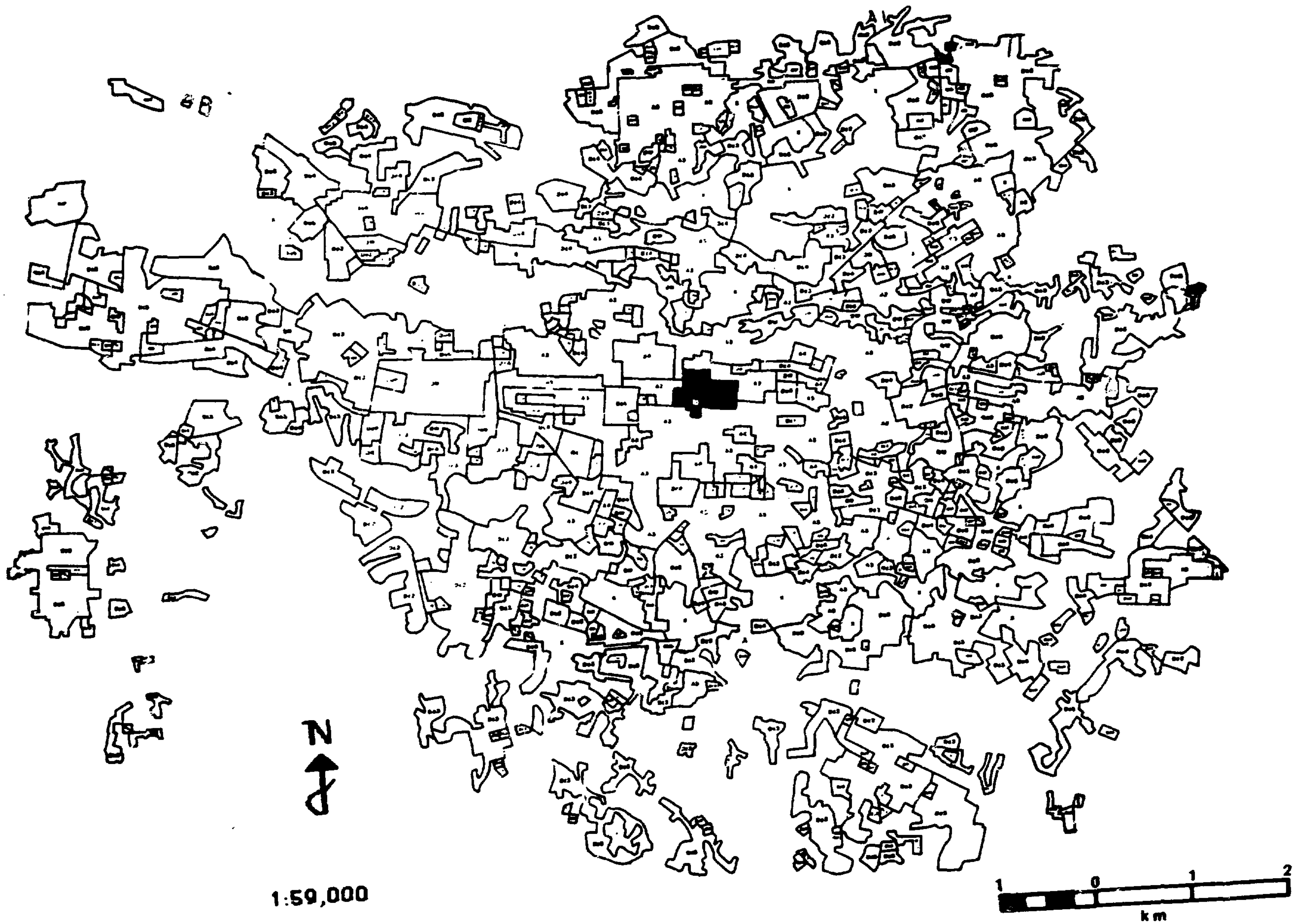
Kuala Lumpur: Administrative/cultural (Do6)



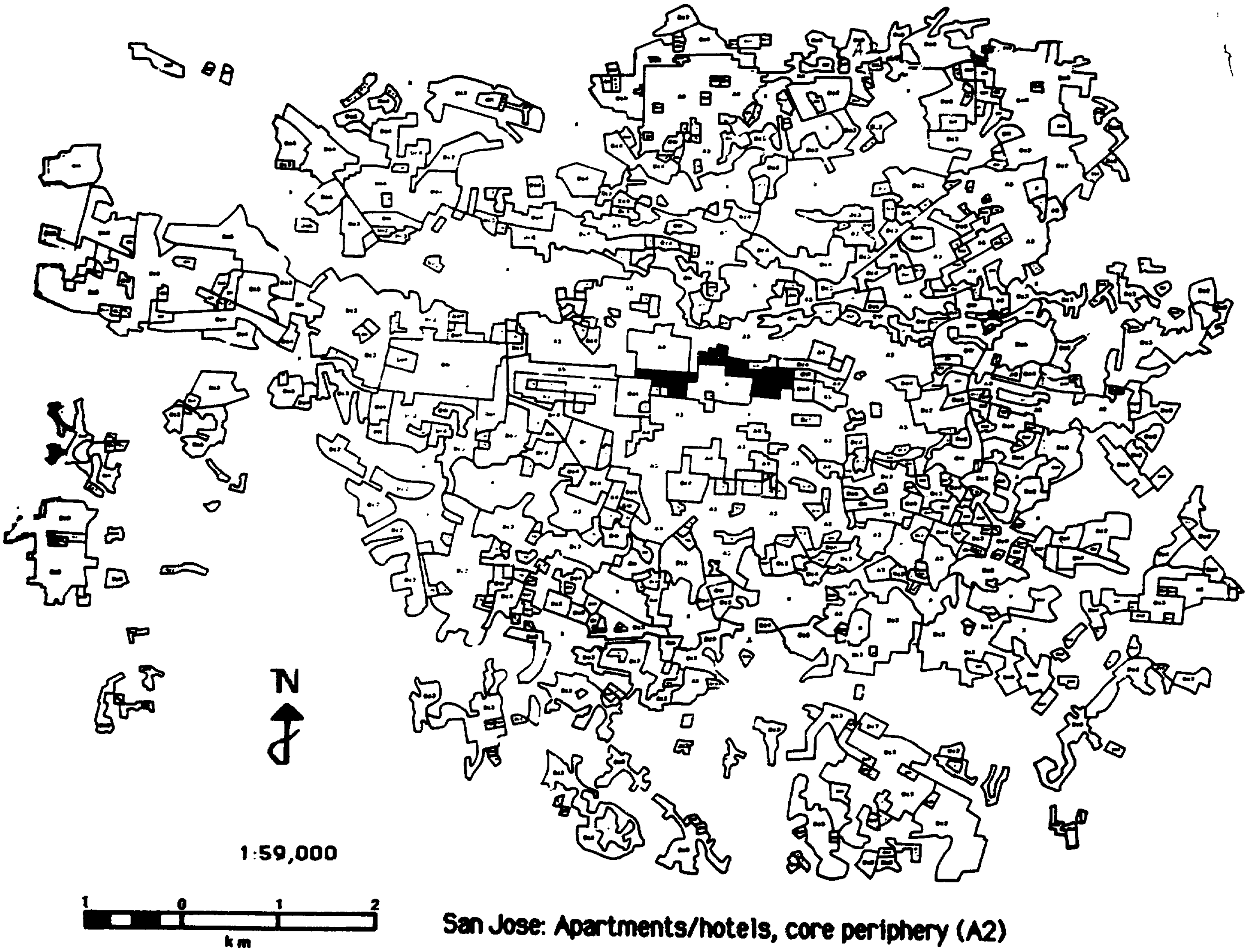
Kuala Lumpur: Open Space, not built upon (ON)



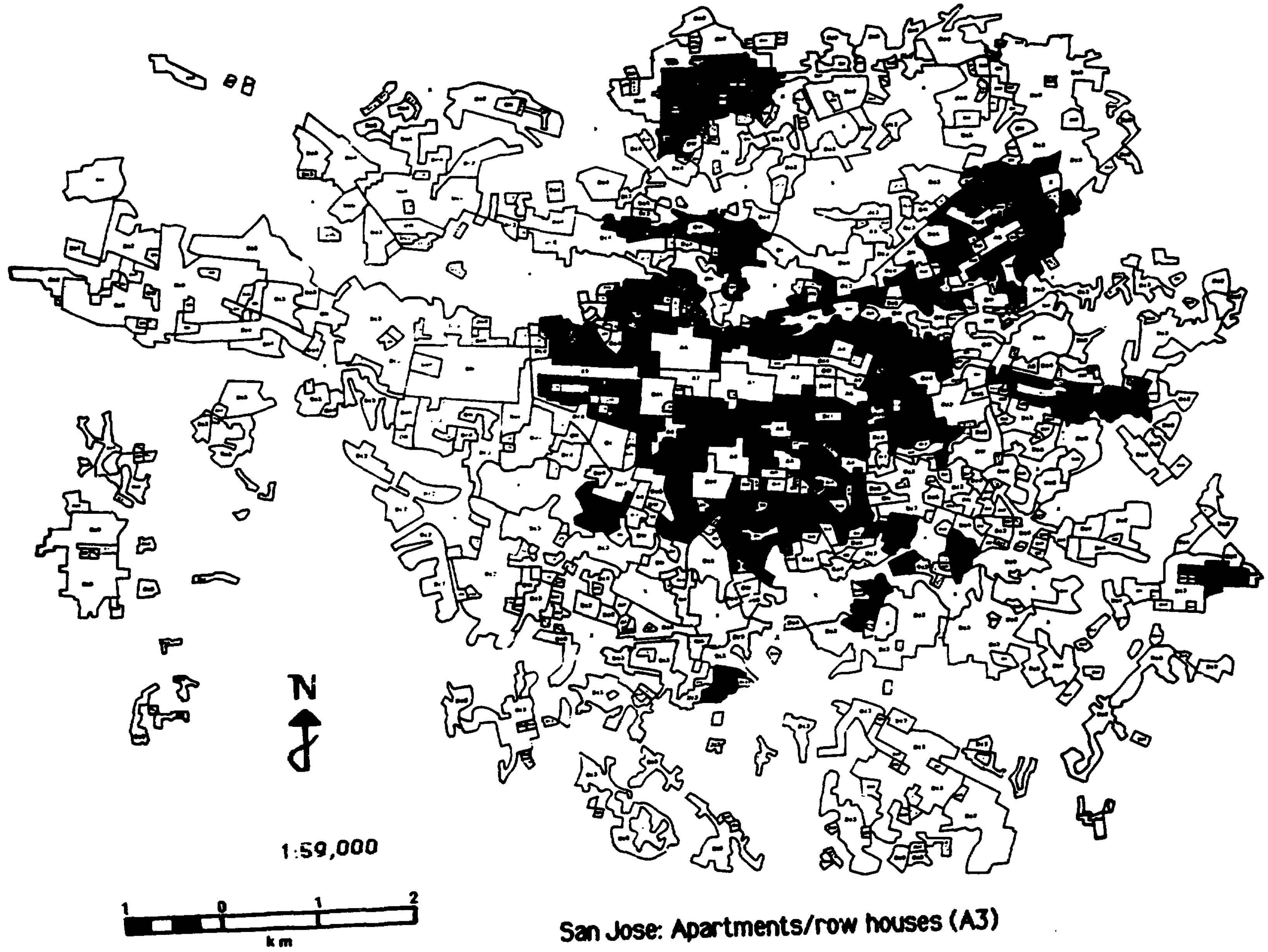
Kuala Lumpur: Open Space, wooded, not built upon (OW)



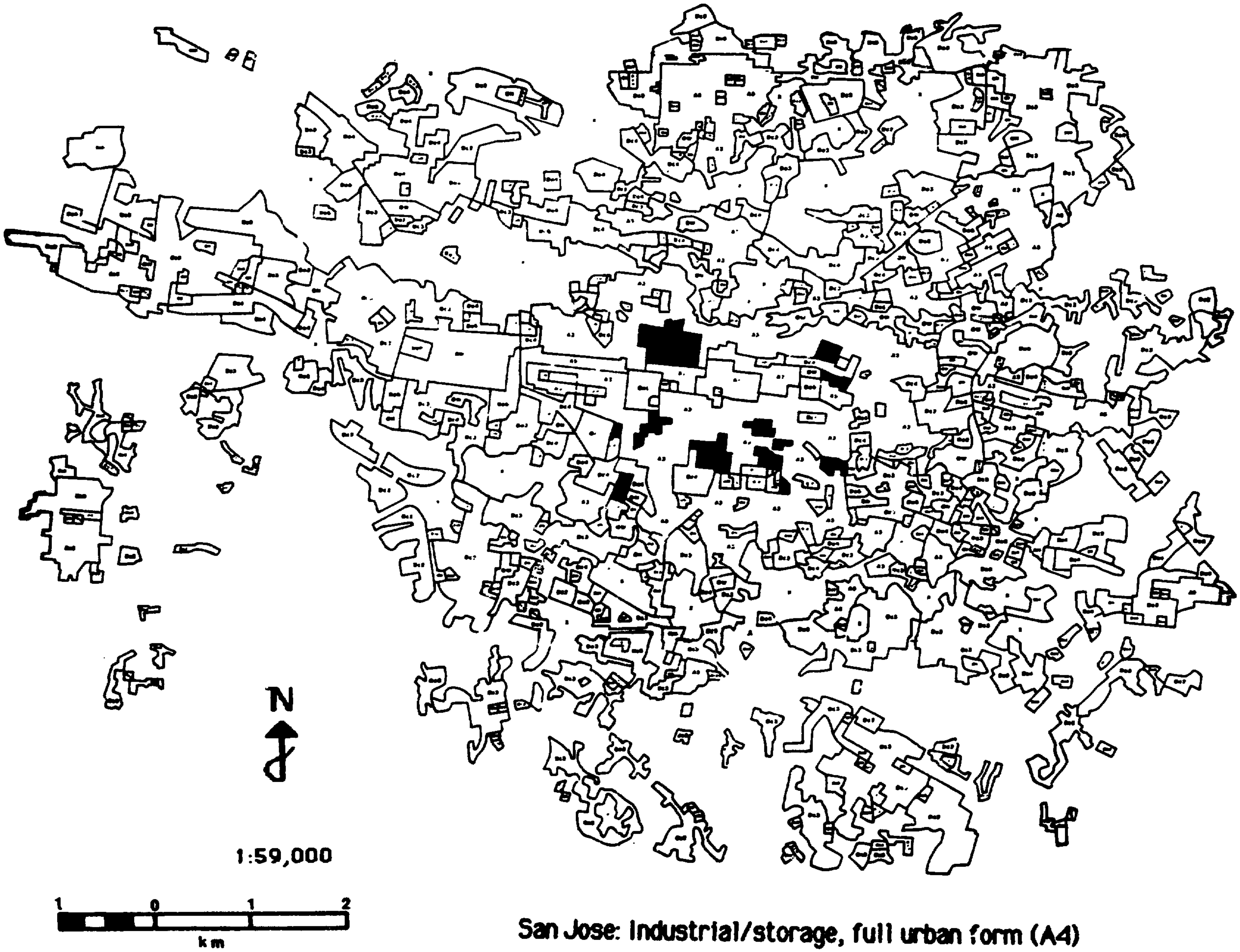
San Jose: Core Area (A1)



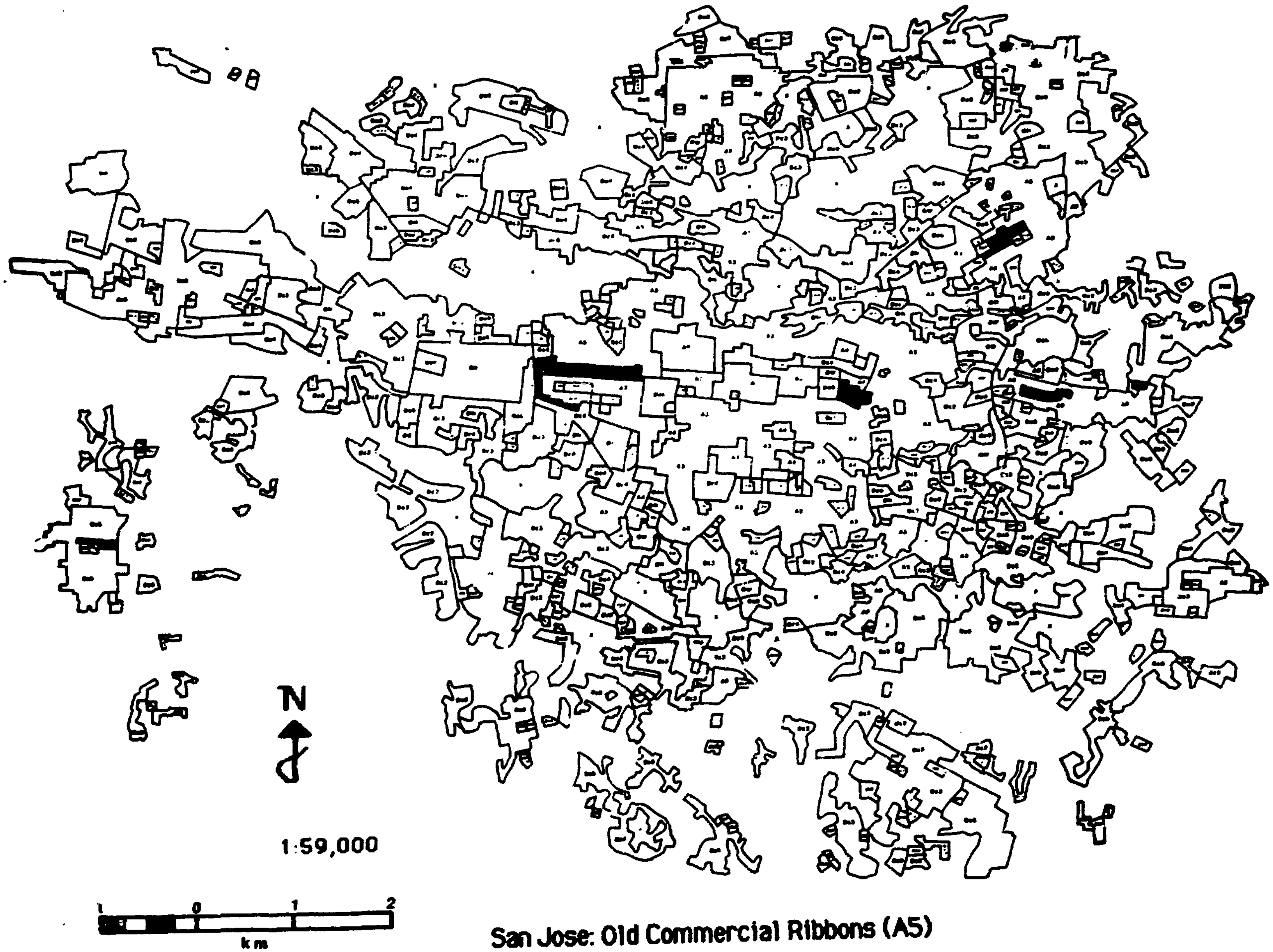
San Jose: Apartments/hotels, core periphery (A2)



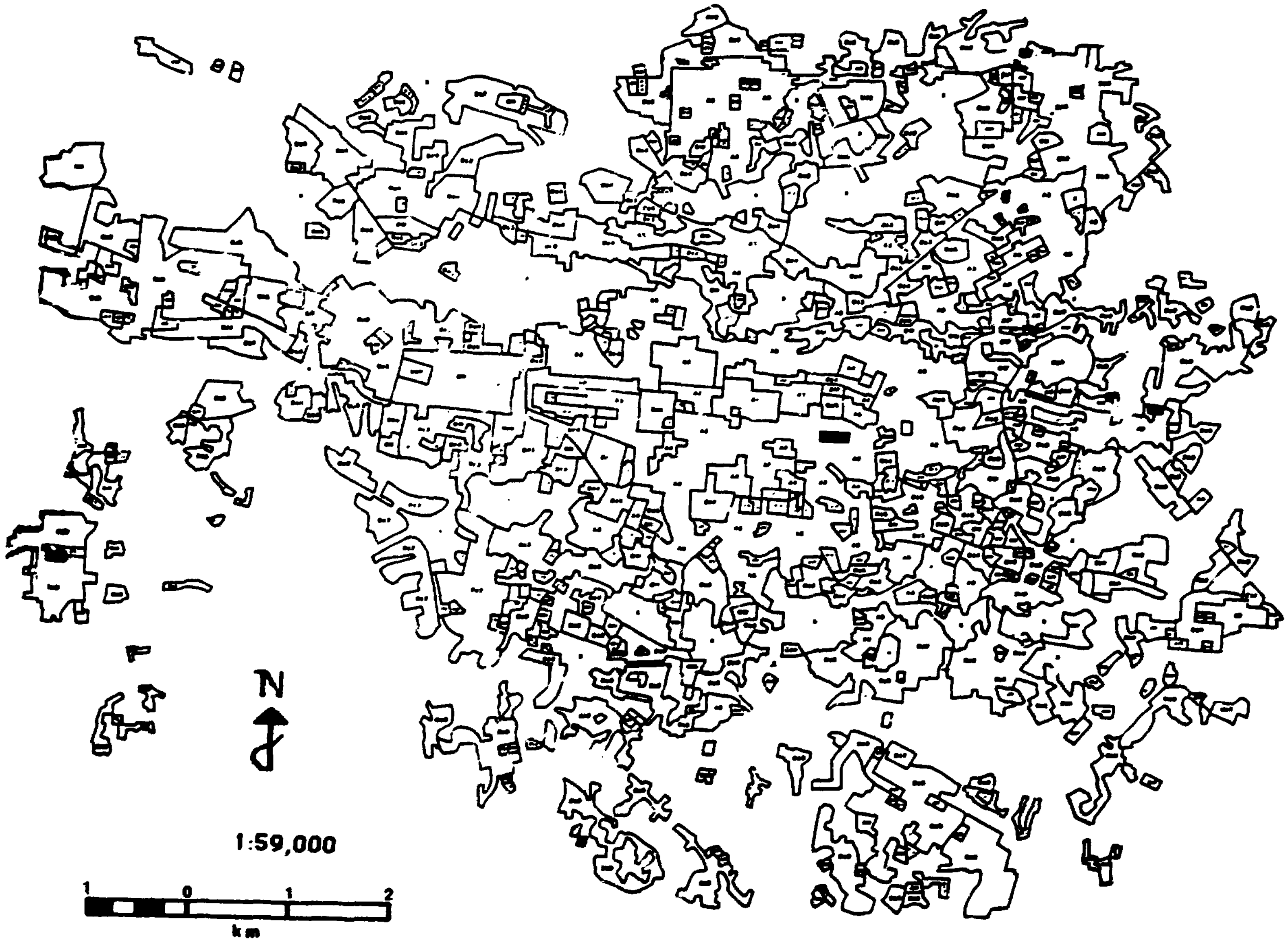
San Jose: Apartments/row houses (A3)



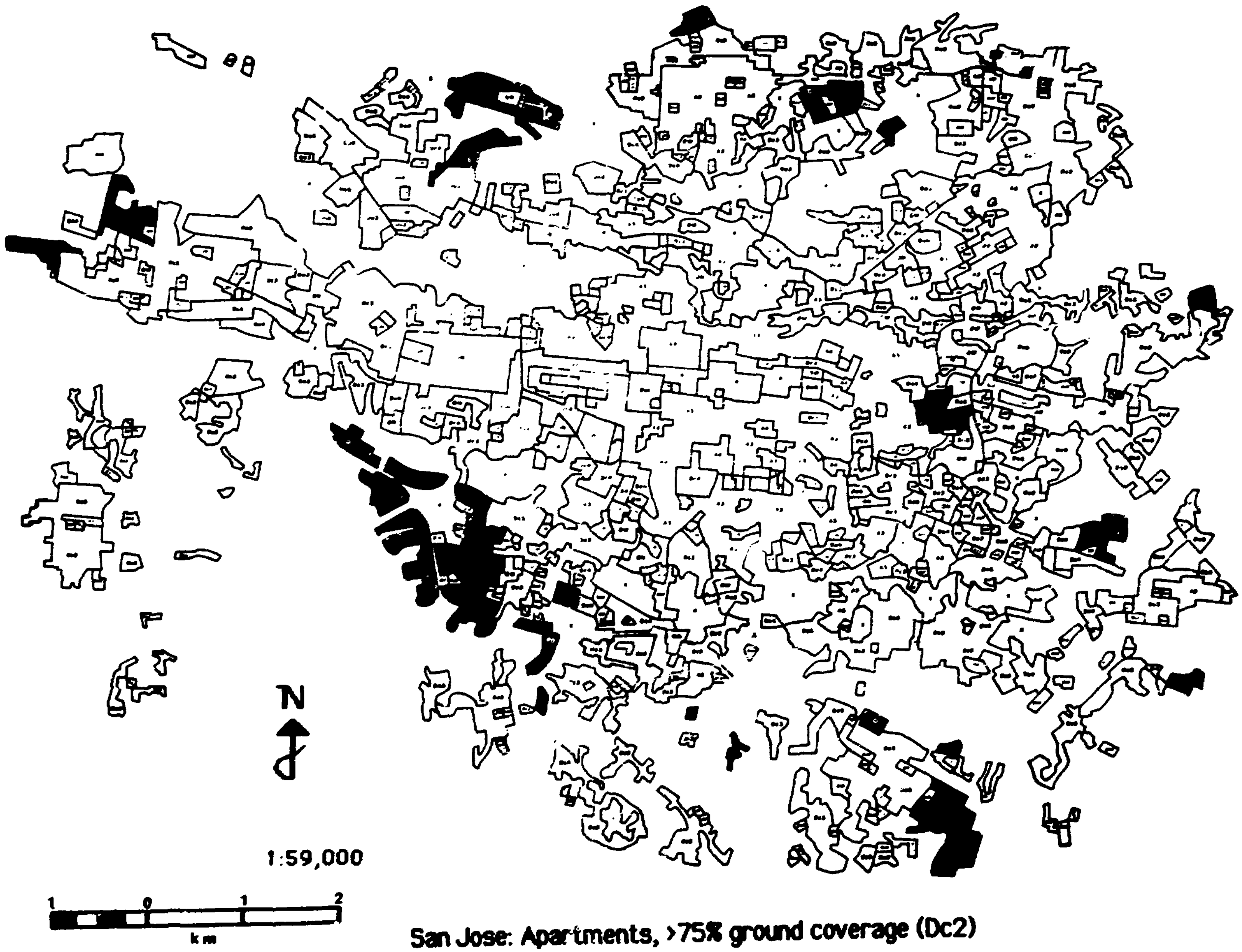
San Jose: Industrial/storage, full urban form (A4)



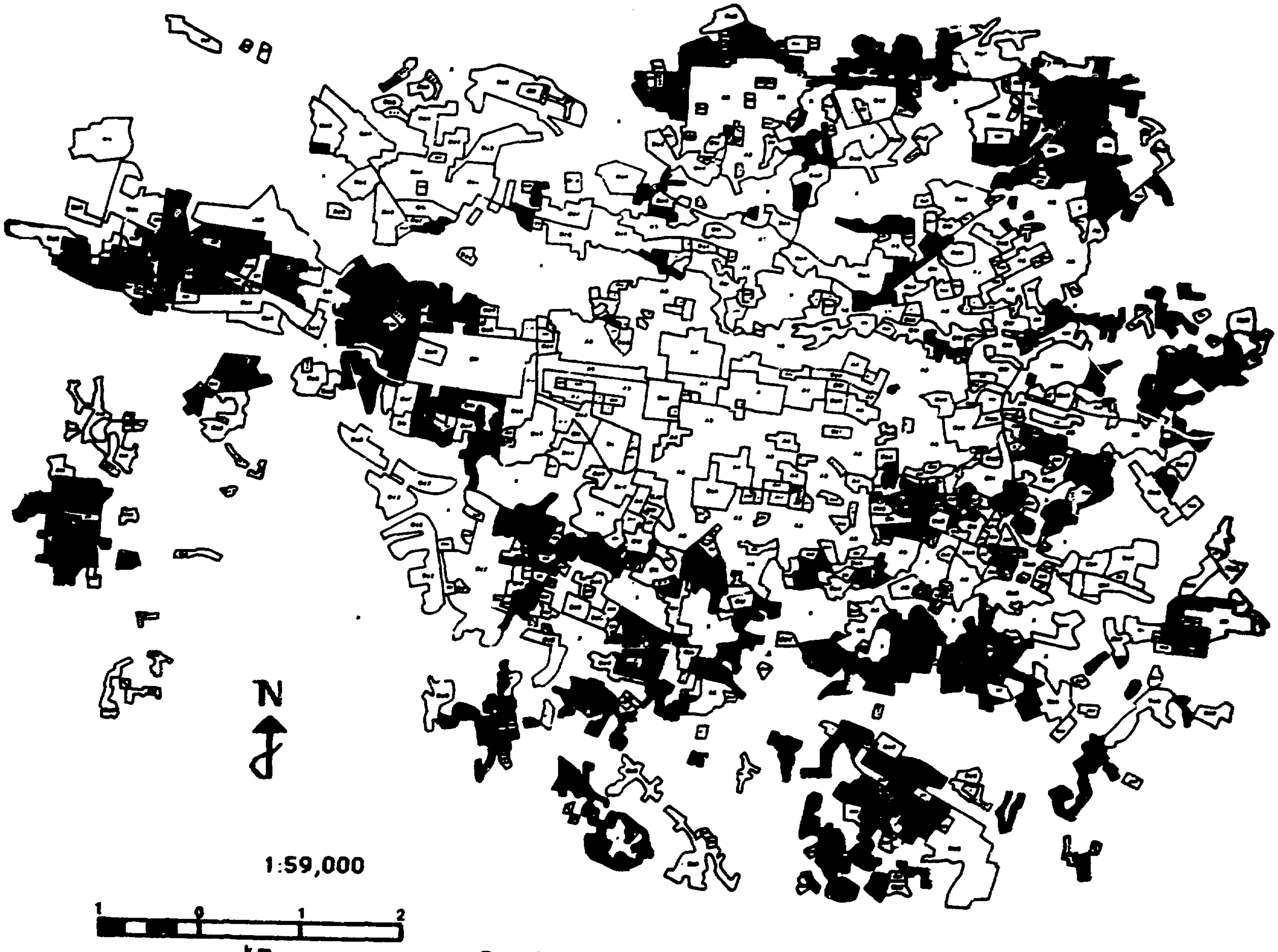
San Jose: Old Commercial Ribbons (A5)



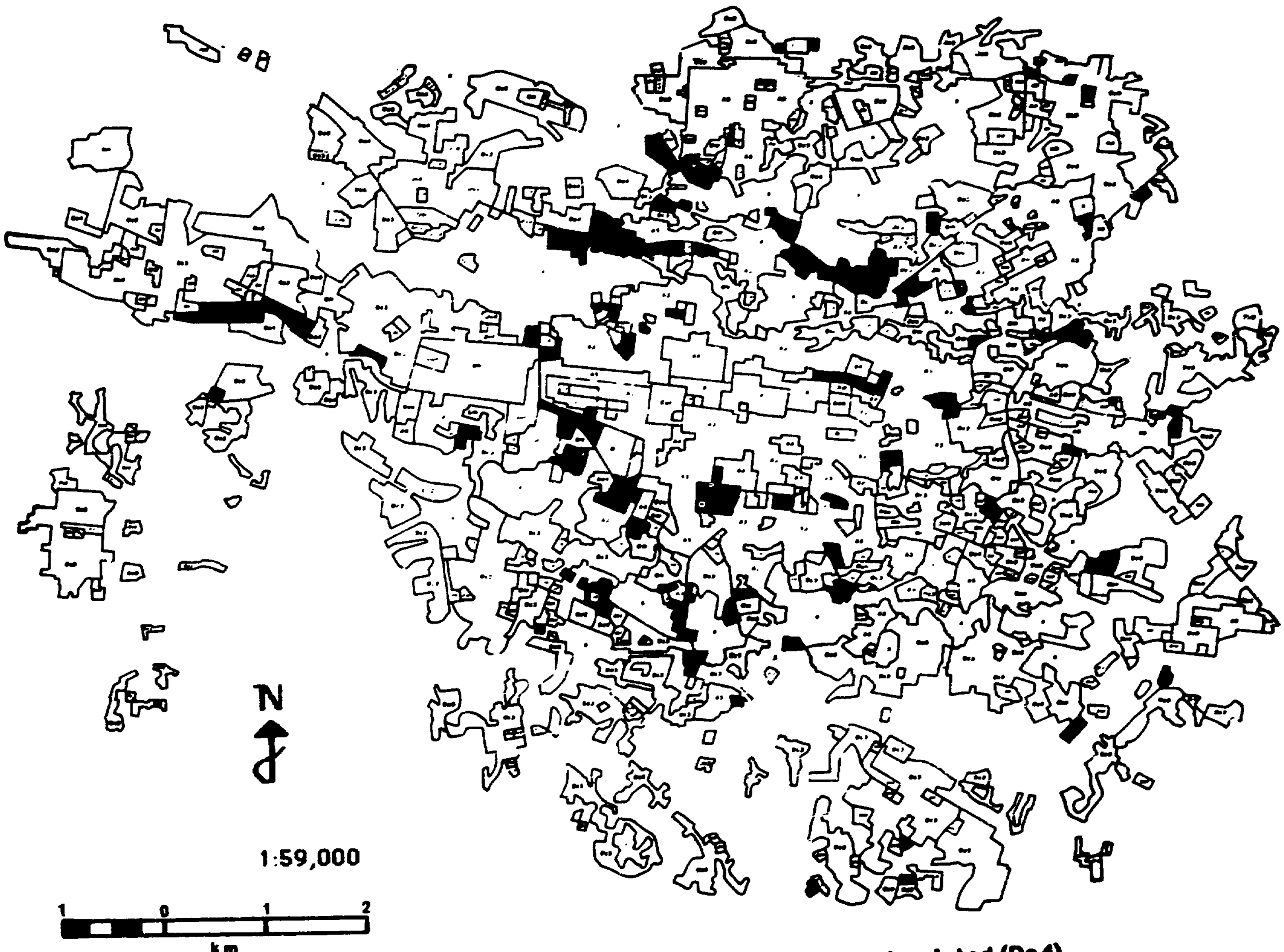
San Jose: Urban Redeveloped core area (Dc1)



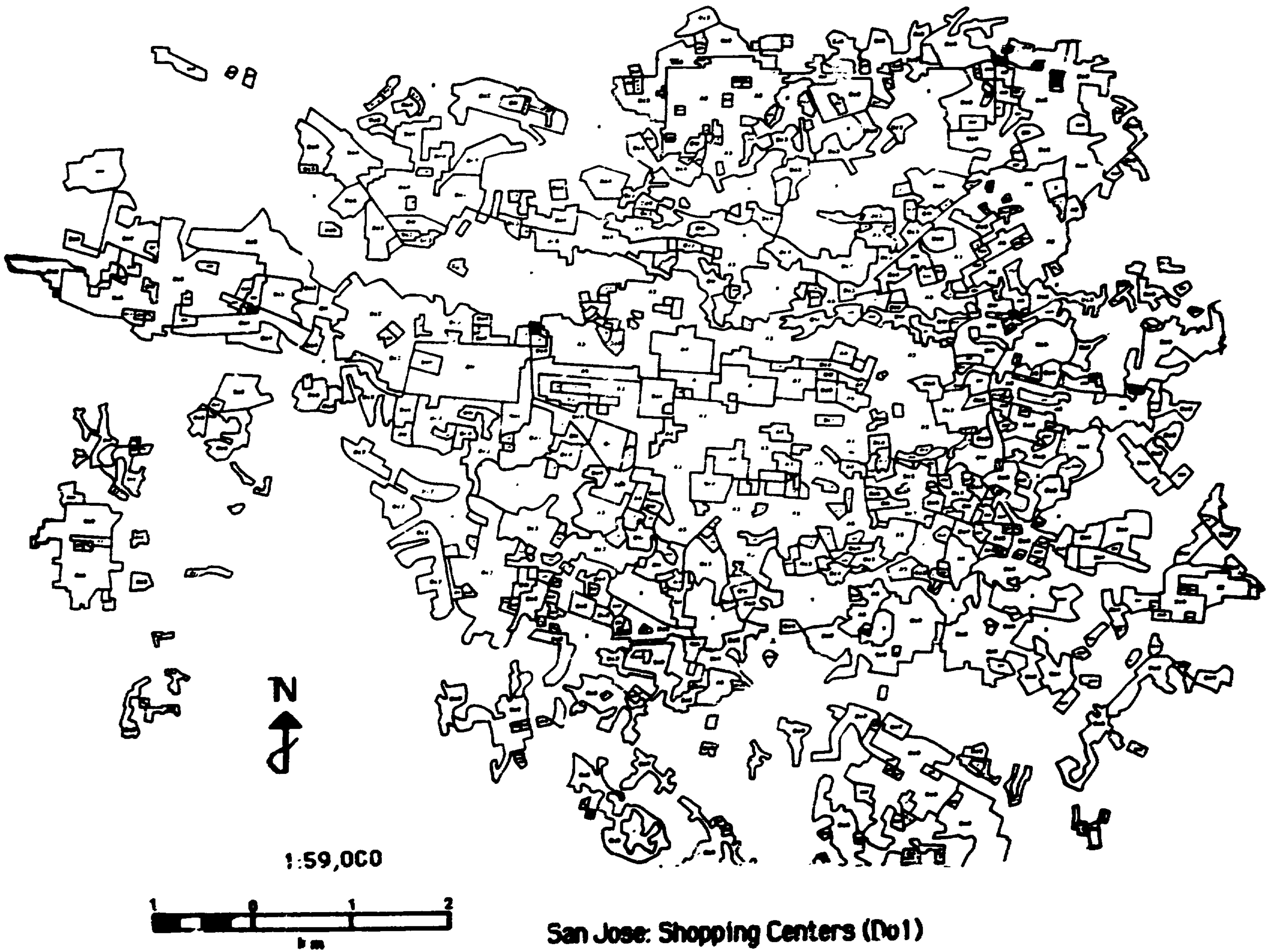
San Jose: Apartments, >75% ground coverage (Dc2)



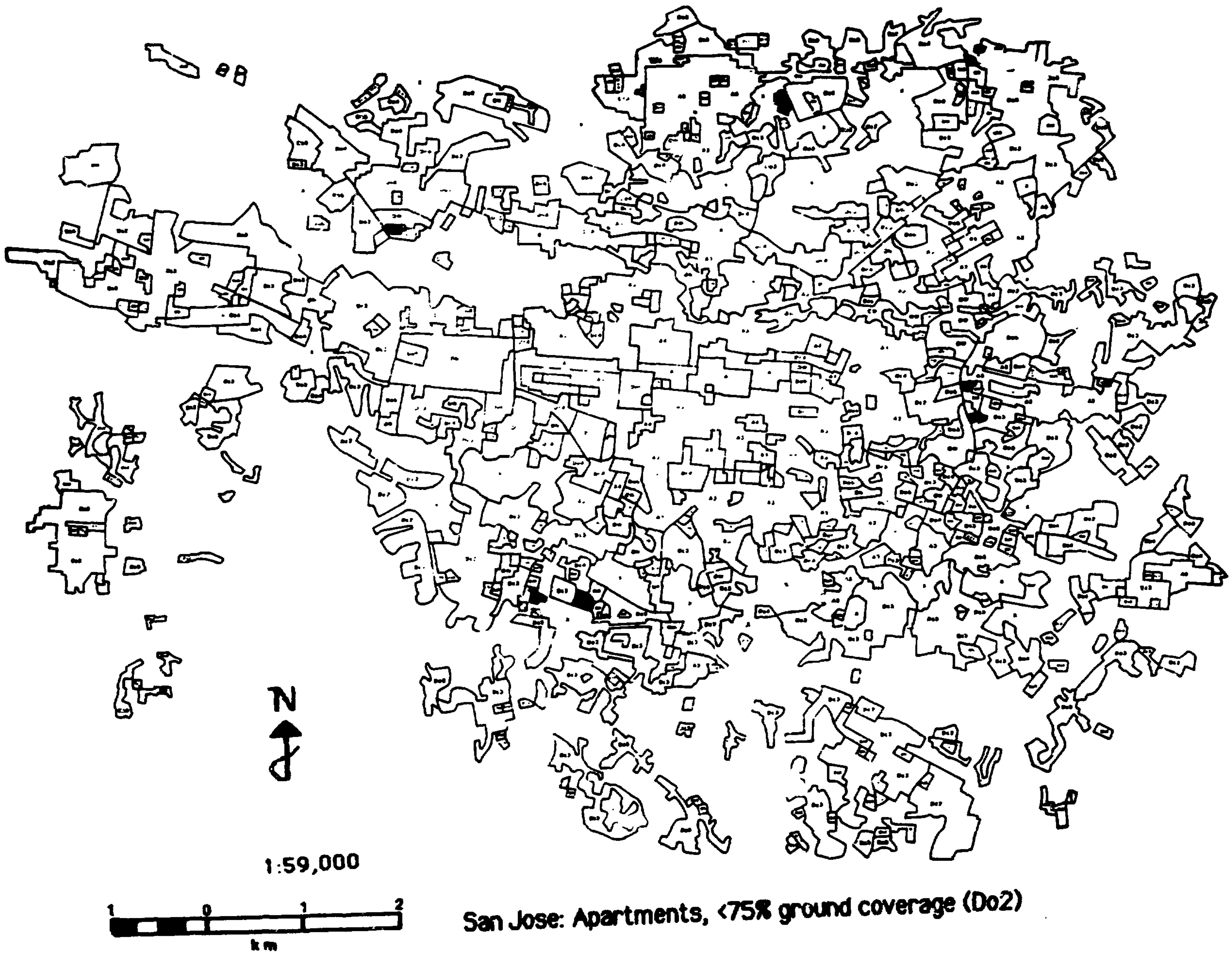
San Jose: Houses, >75% ground coverage (Dc3)



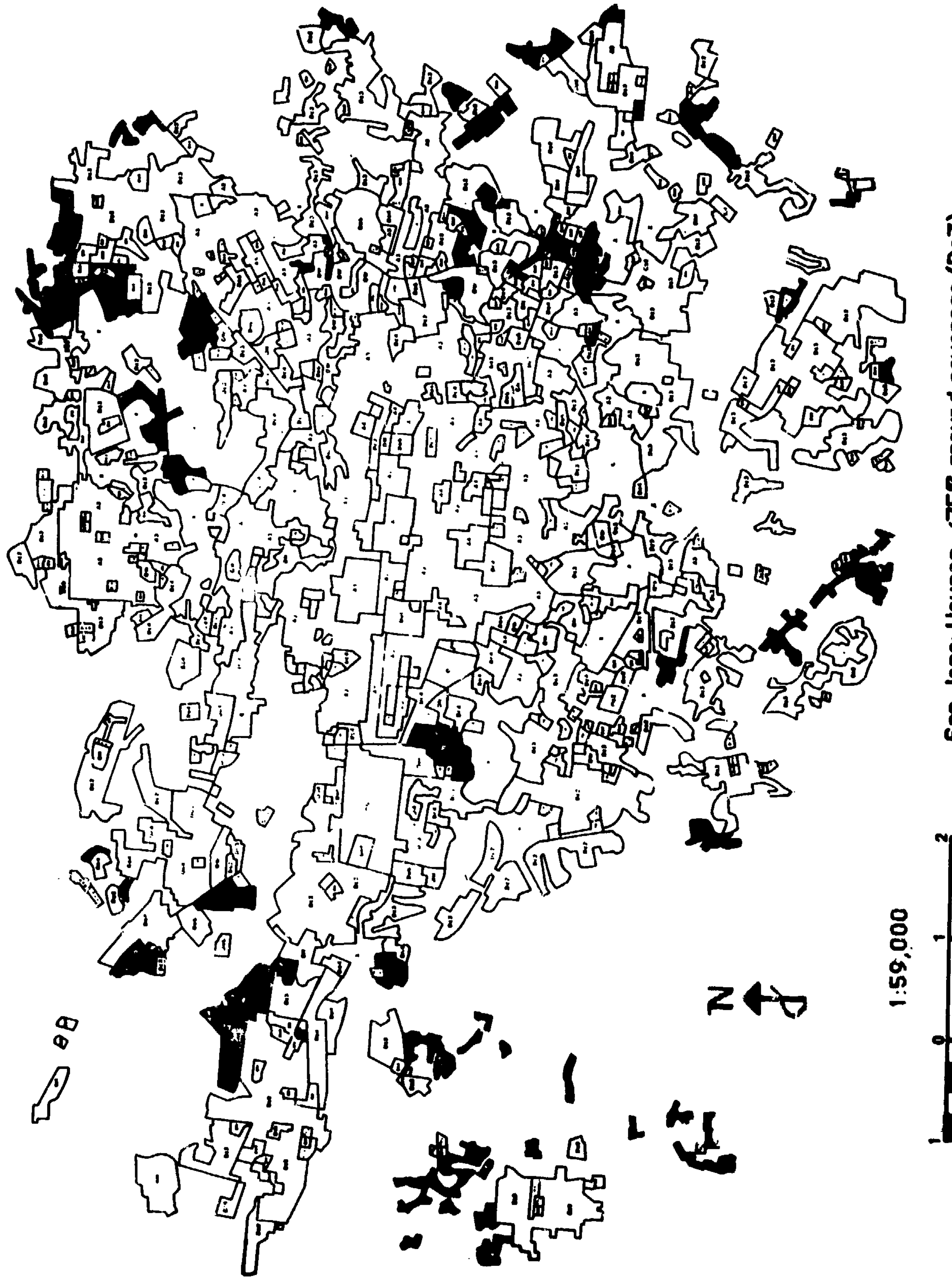
San Jose: Industrial/storage, RR or dock-related (Dc4)



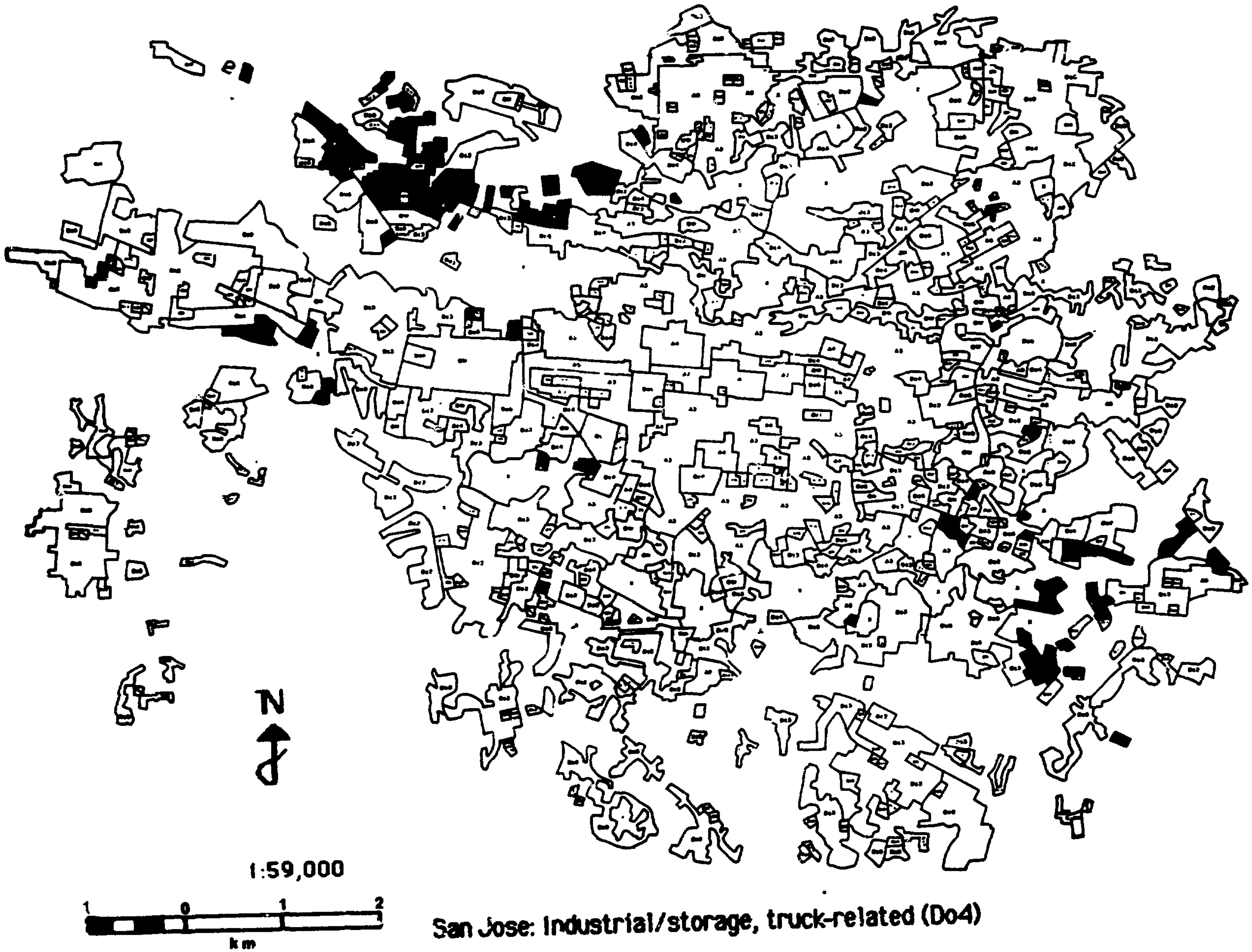
San Jose: Shopping Centers (Do1)



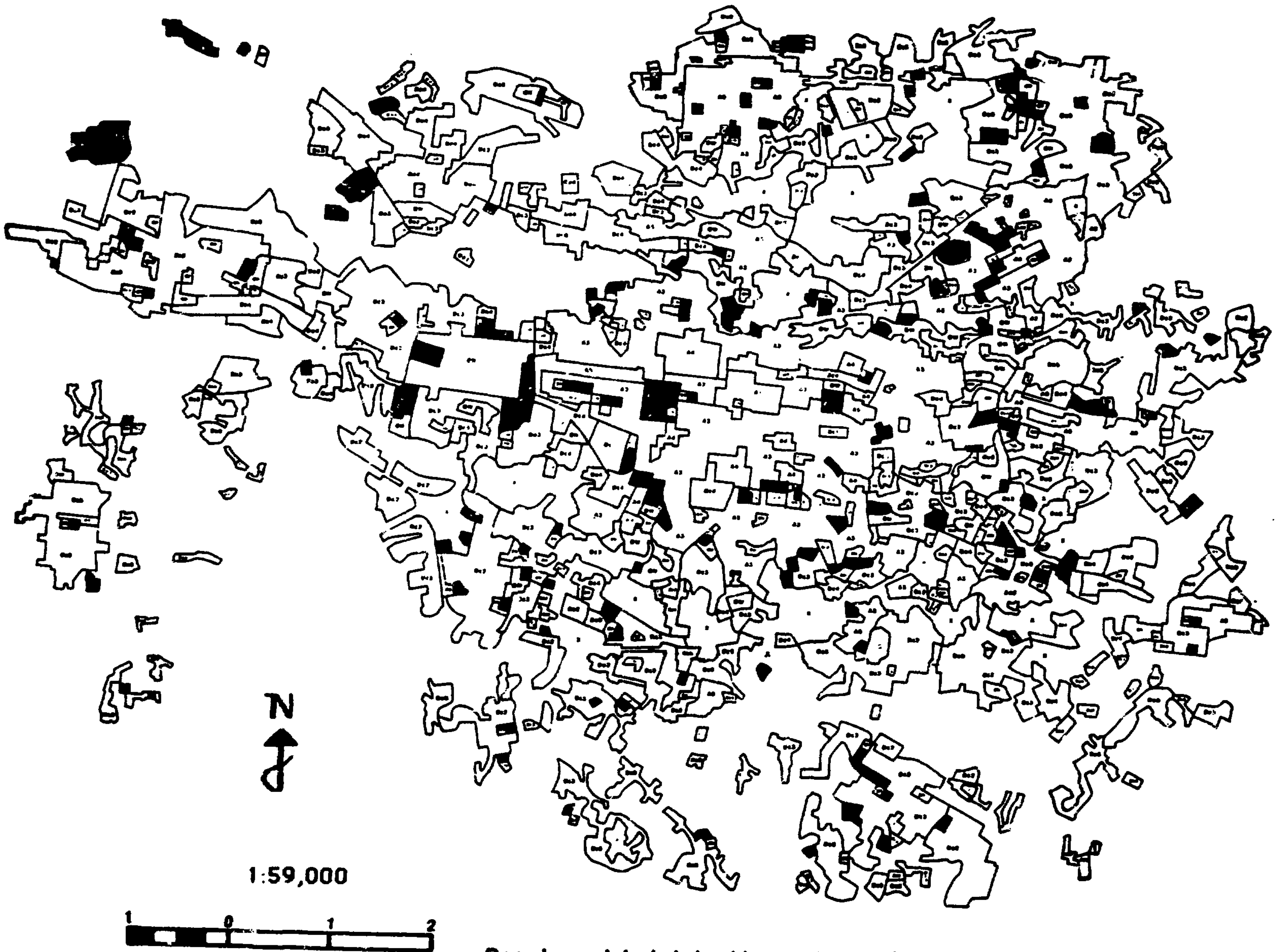
San Jose: Apartments, <75% ground coverage (Do2)



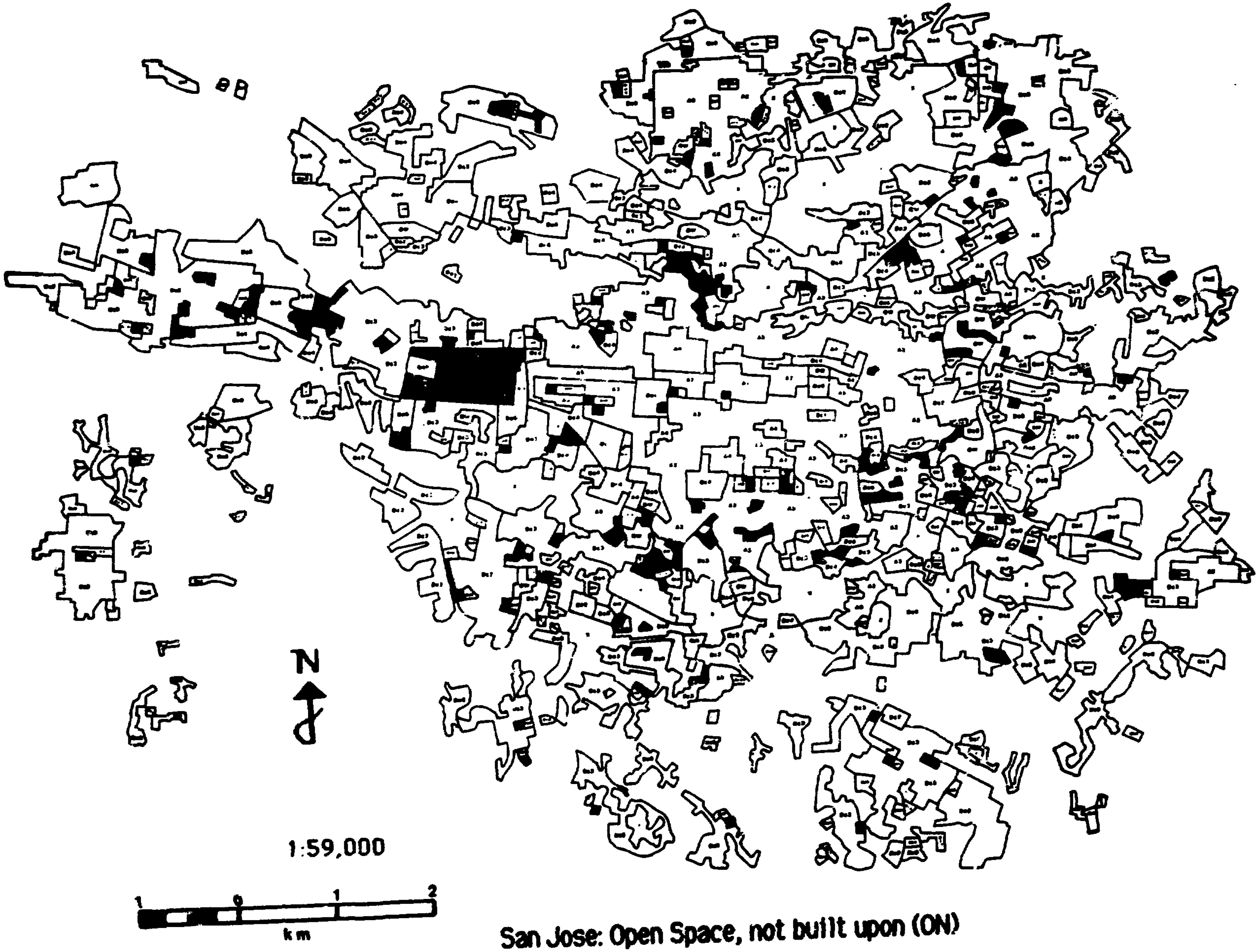
San Jose: Houses, <75% ground coverage (Do3)



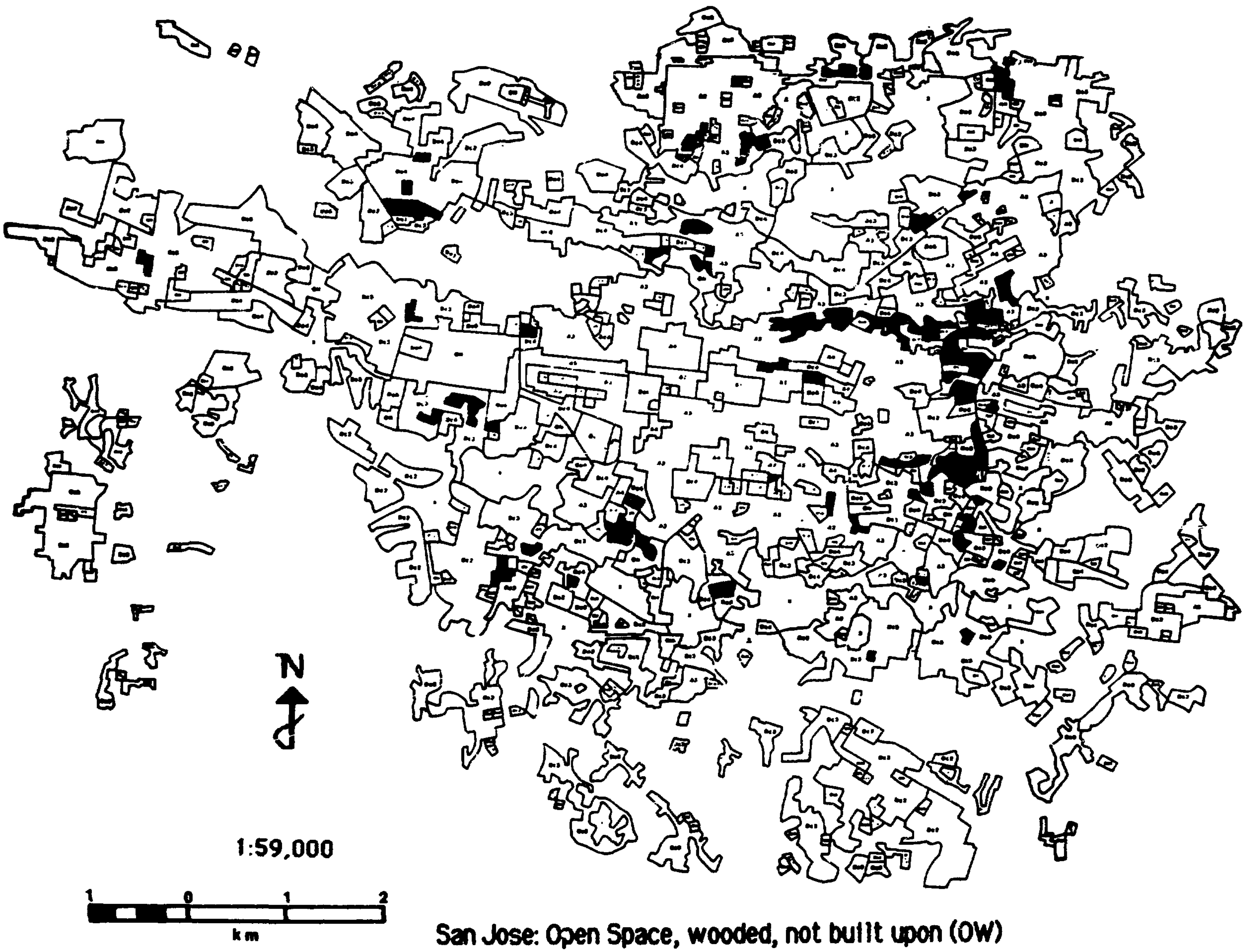
San Jose: Industrial/storage, truck-related (Do4)



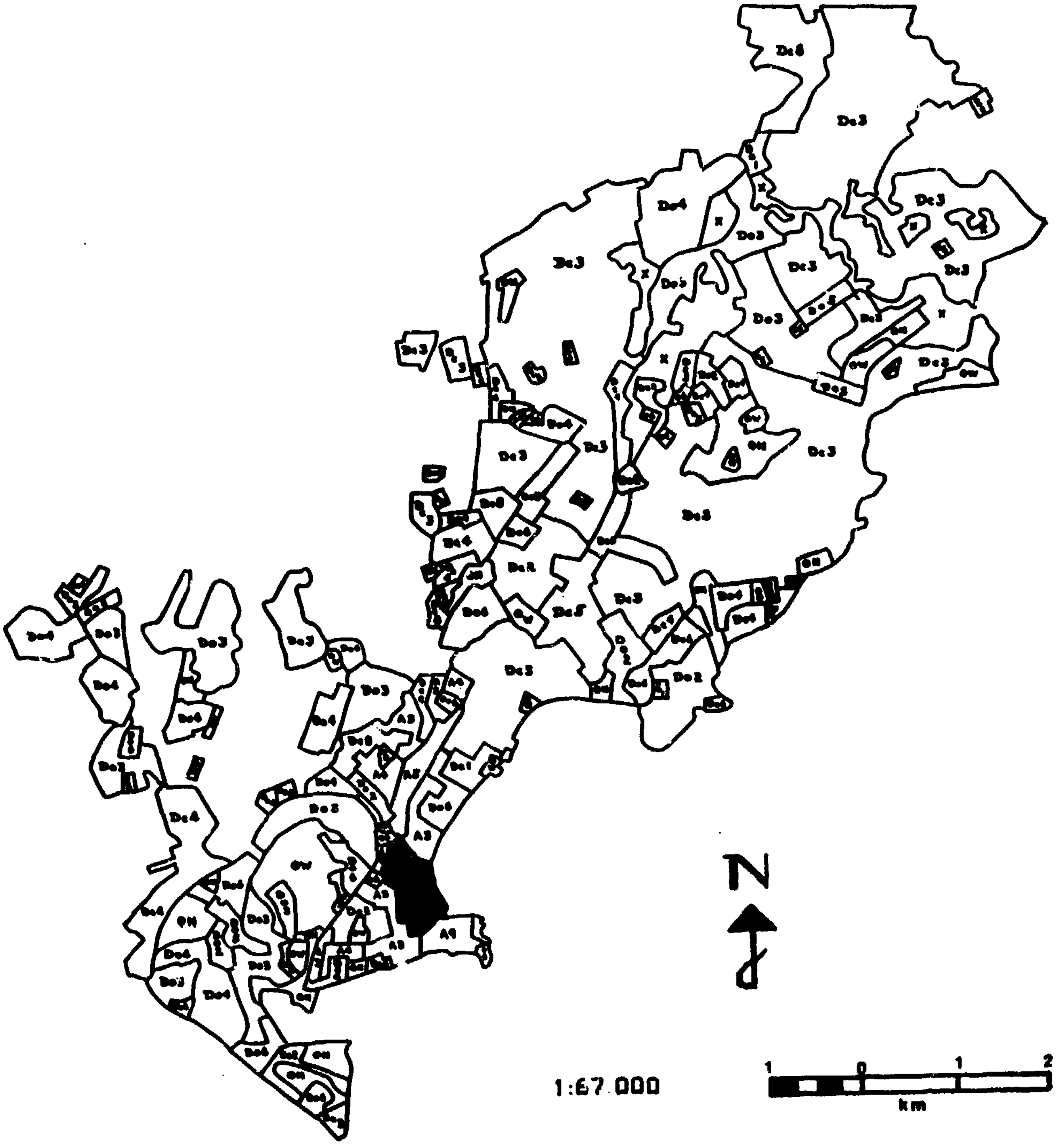
San Jose: Administrative/cultural (Do6)



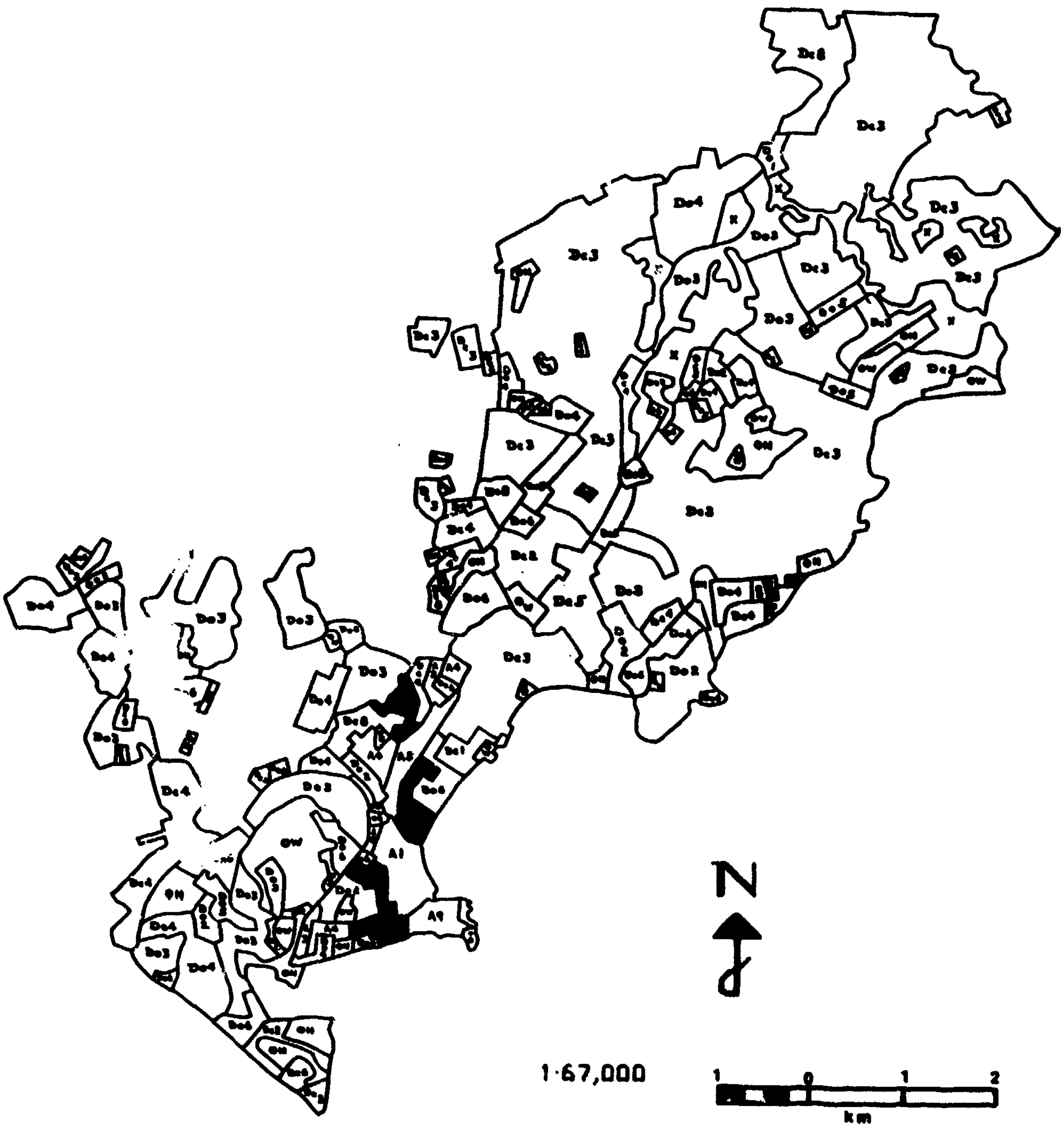
San Jose: Open Space, not built upon (ON)



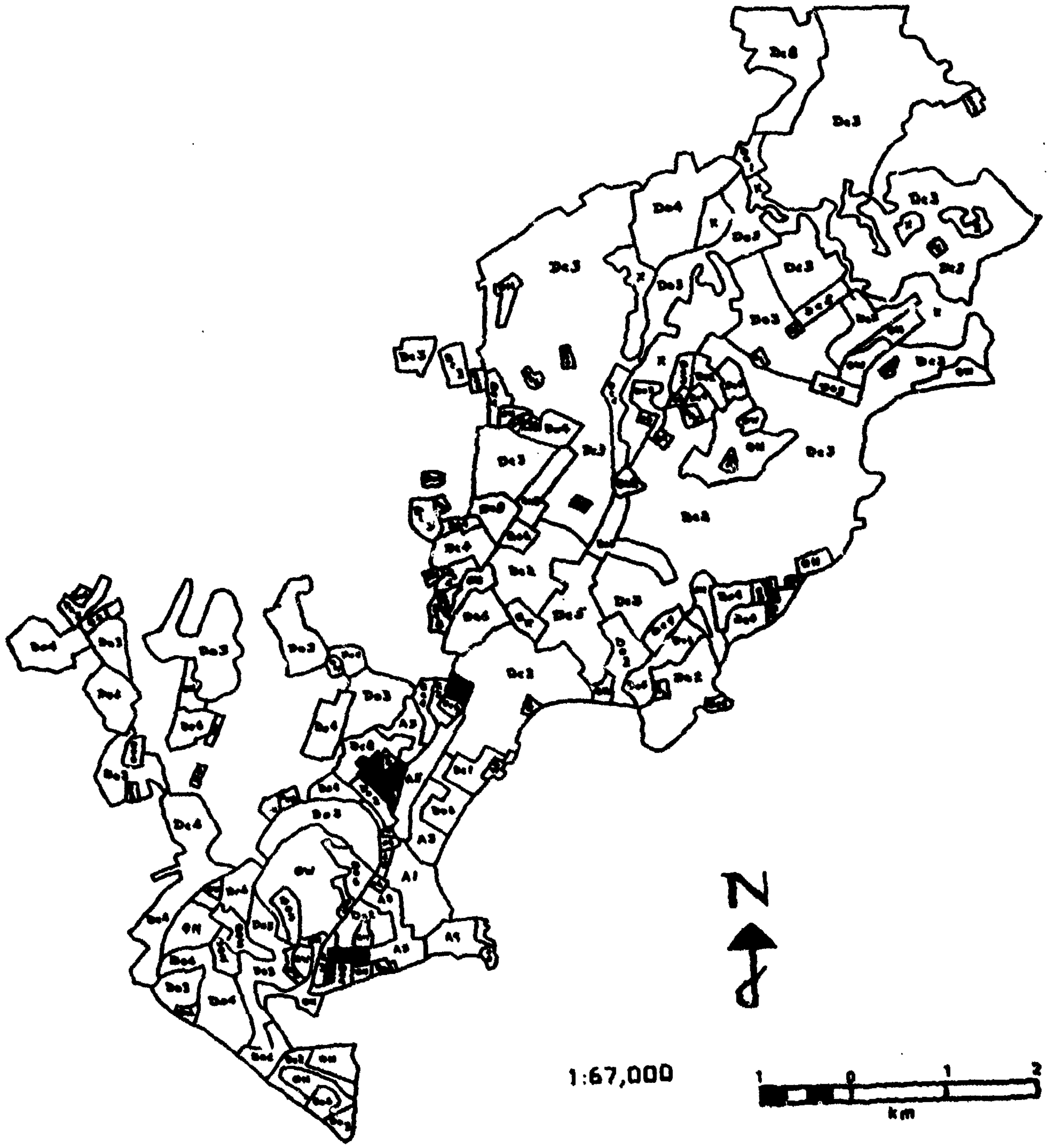
San Jose: Open Space, wooded, not built upon (OW)



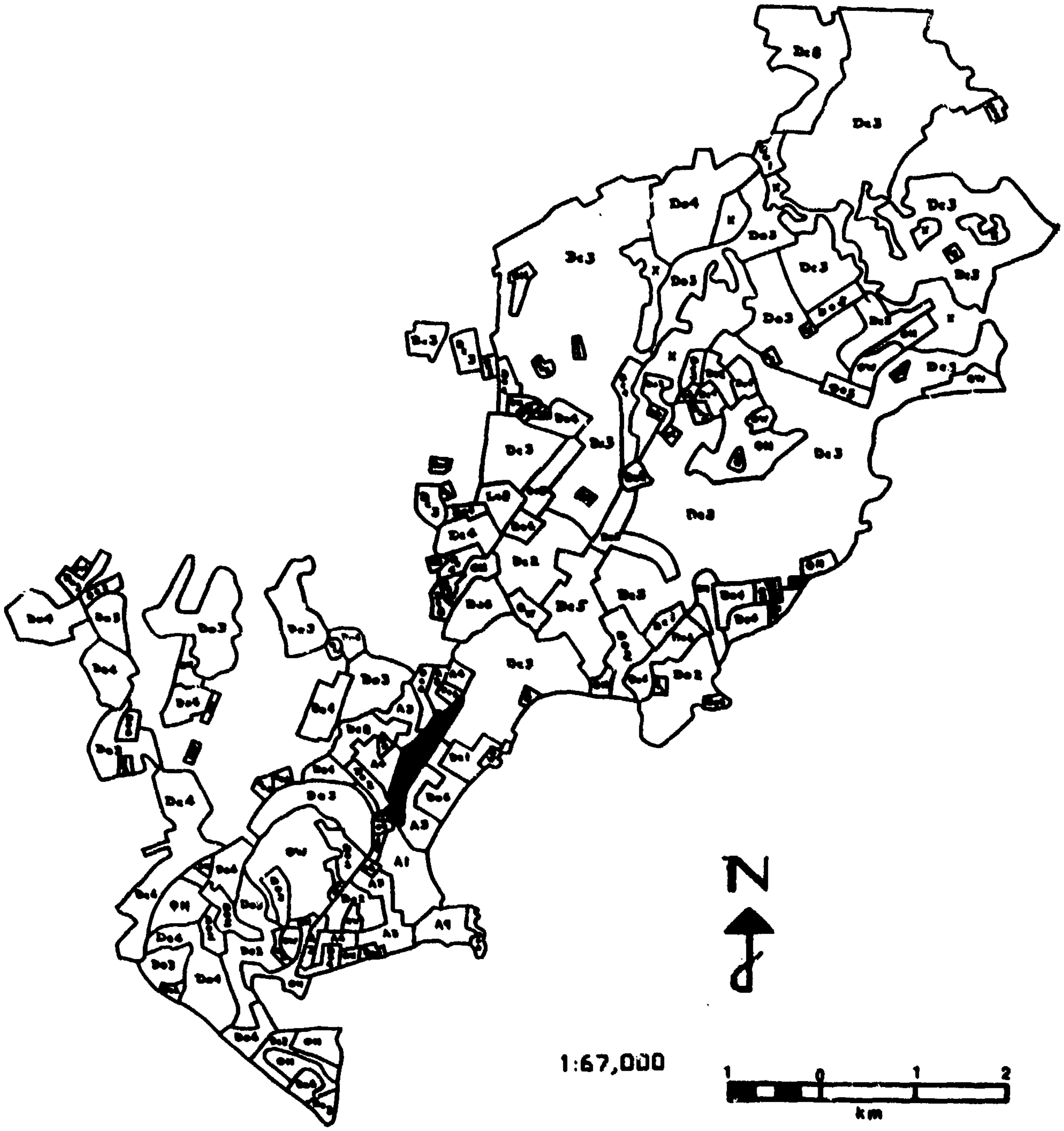
Panama-Balboa: Core Area (A1)



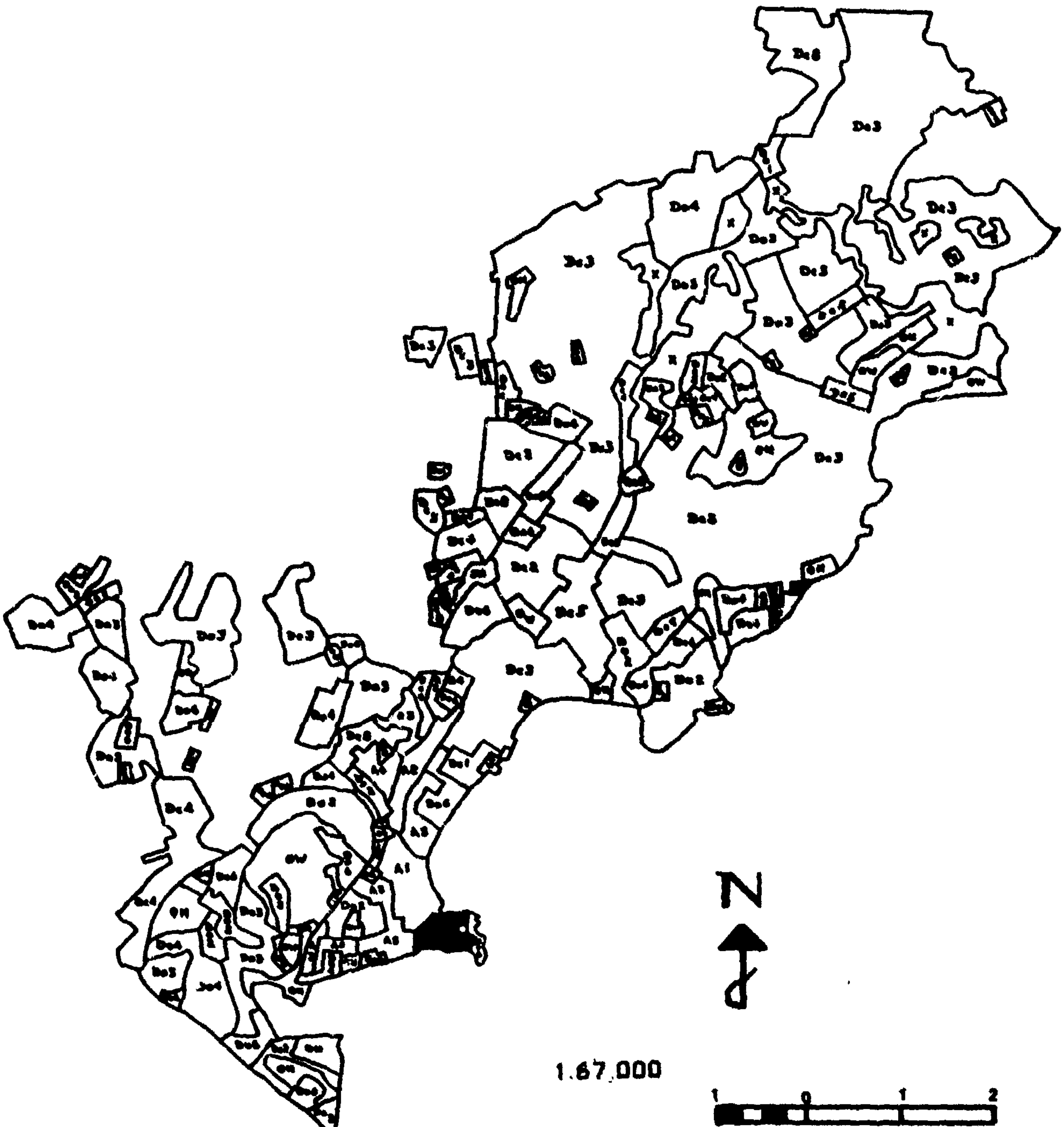
Panama-Balboa: Apartments/row houses (A3)



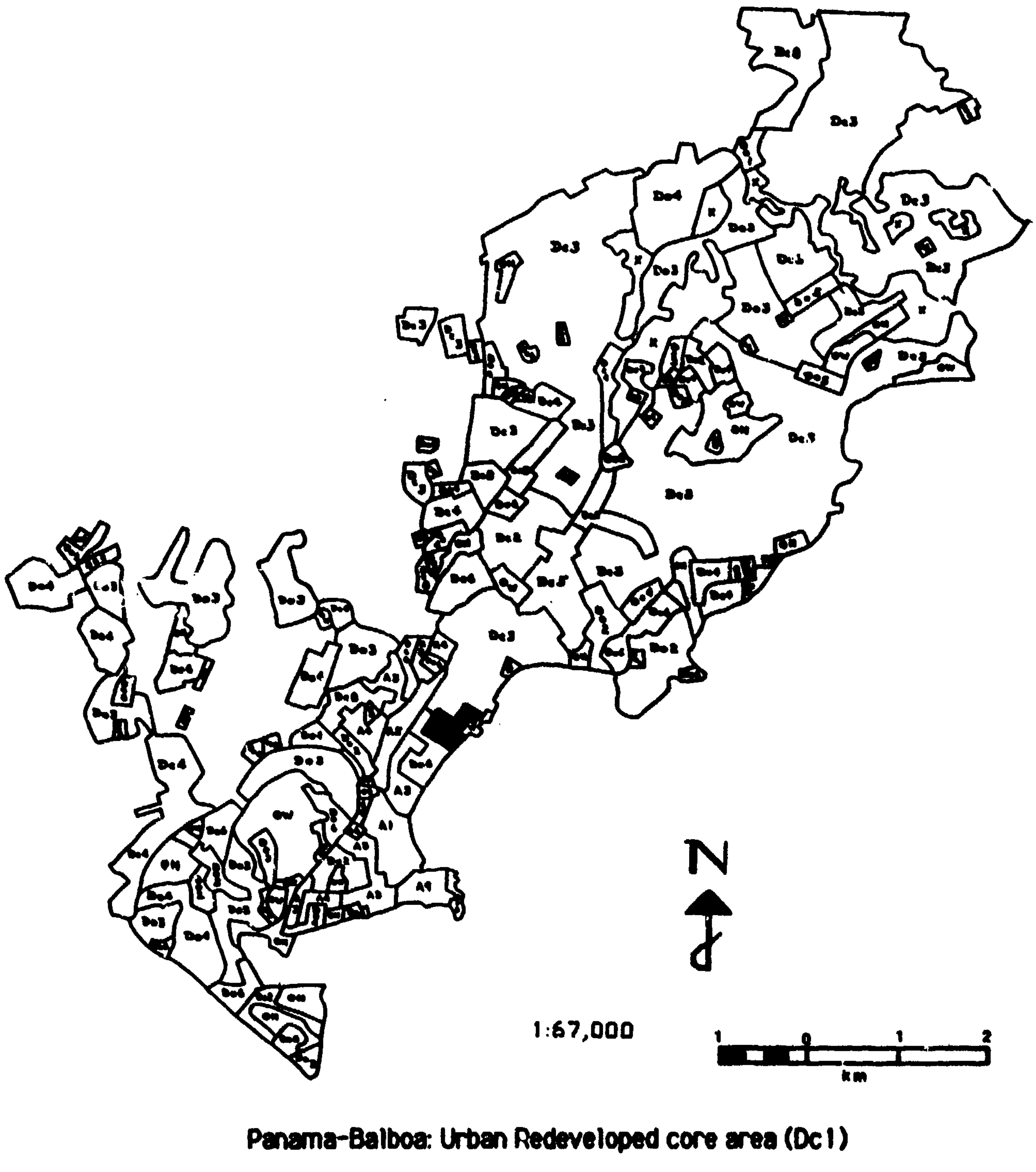
Panama-Balboa: Industrial/storage, full urban form (A4)



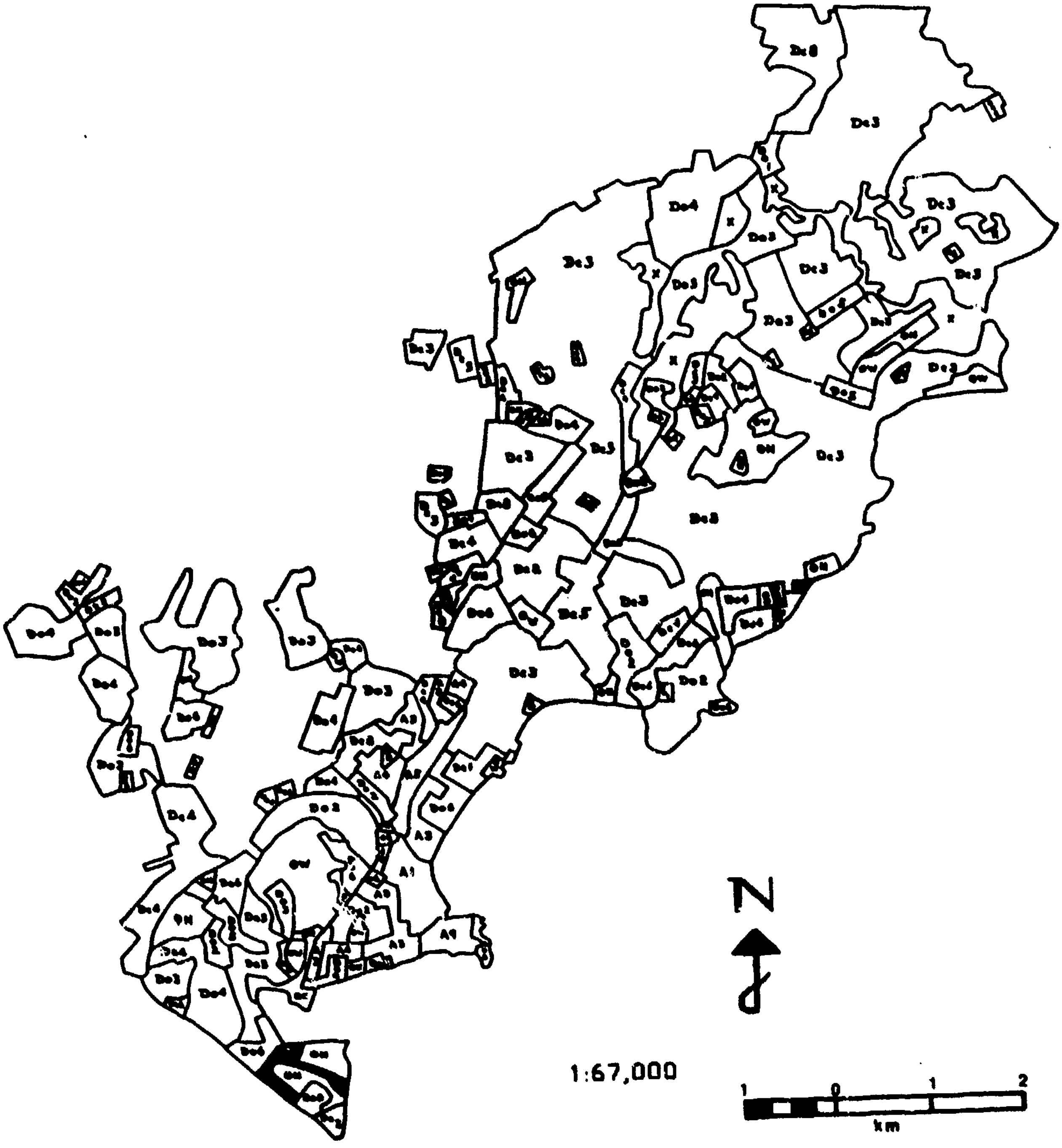
Panama-Balboa: Old Commercial Ribbons (A5)



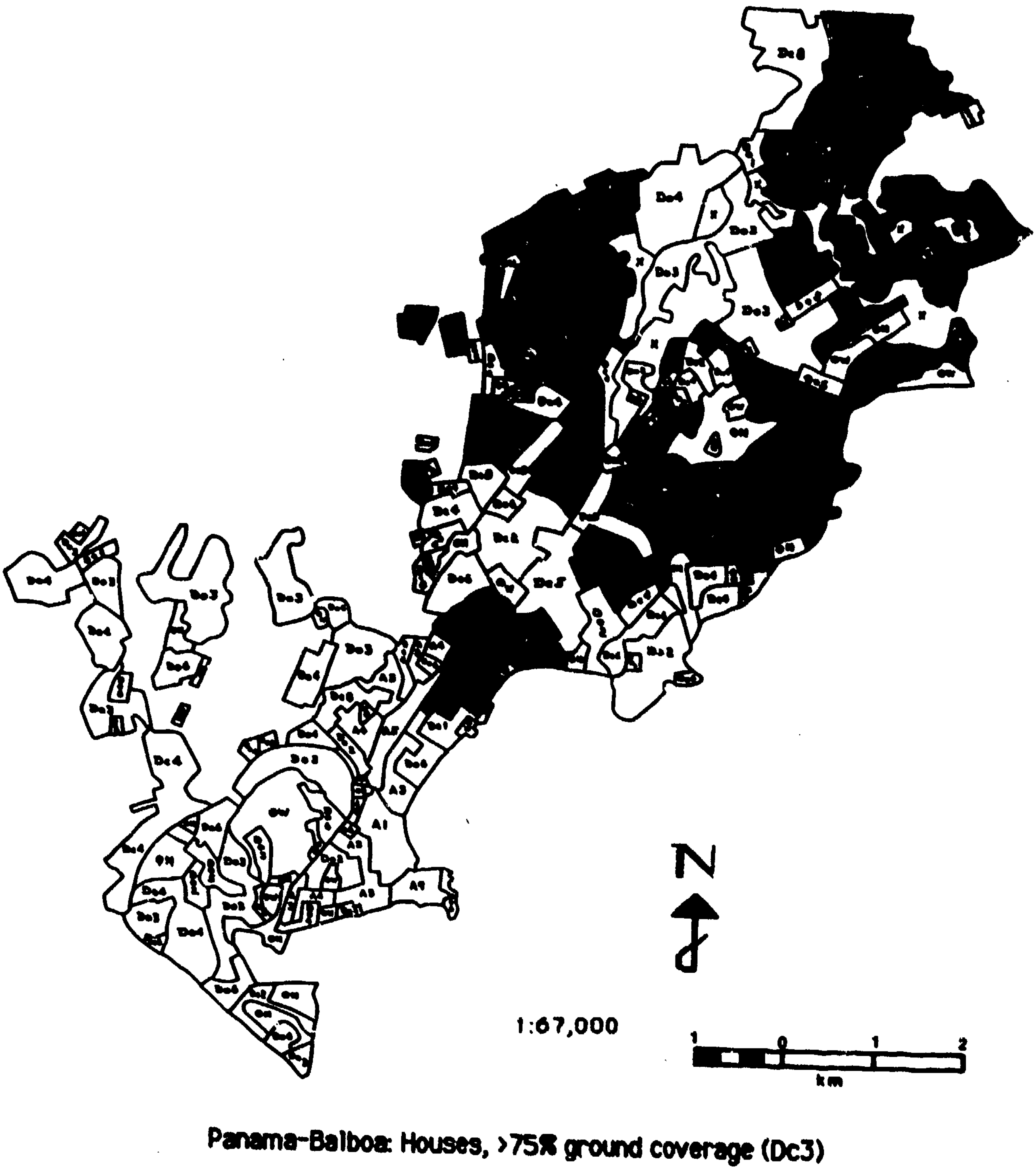
Panama-Balboa: Old Core, vestigial (A9)



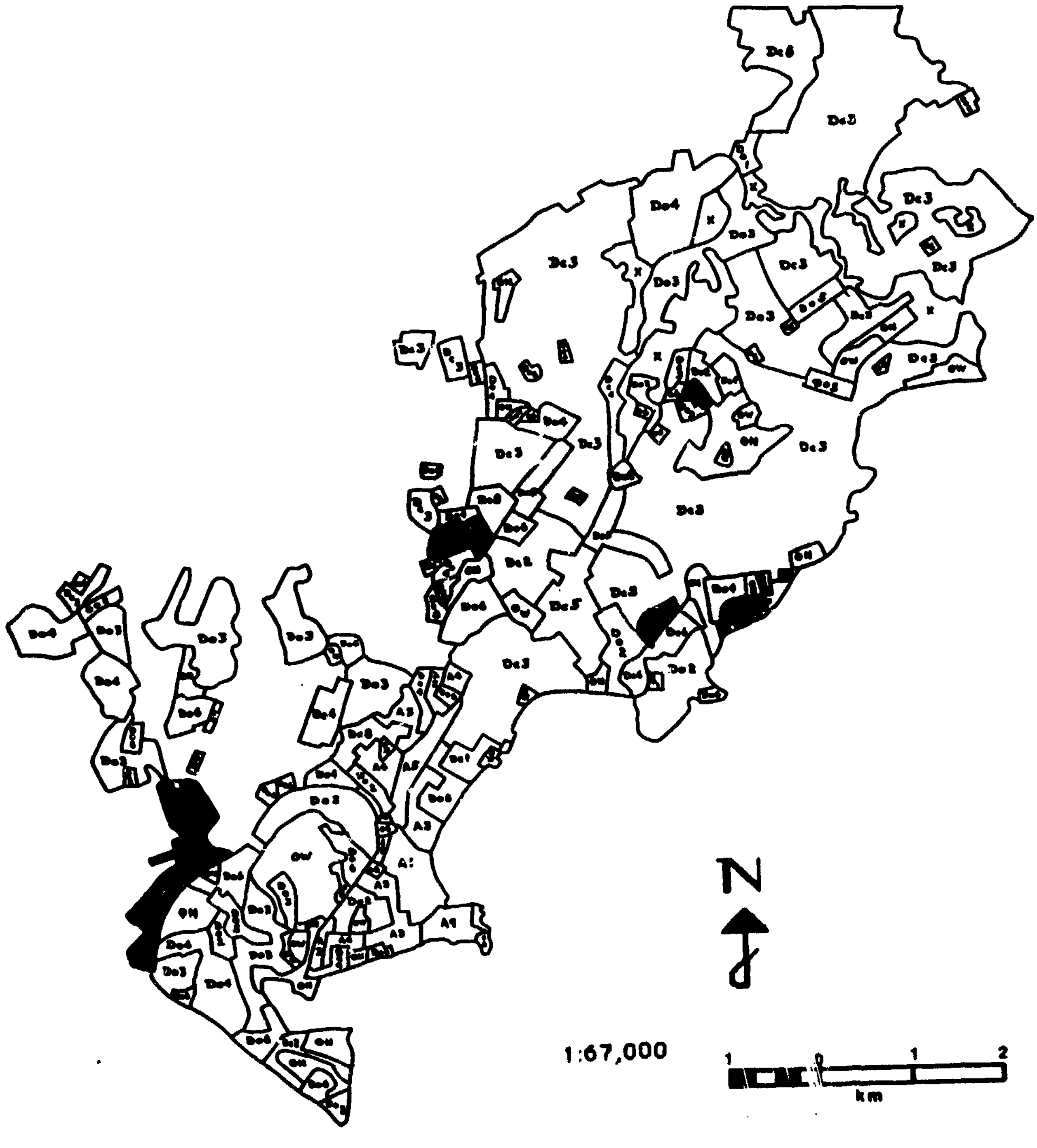
Panama-Balboa: Urban Redeveloped core area (Dc1)



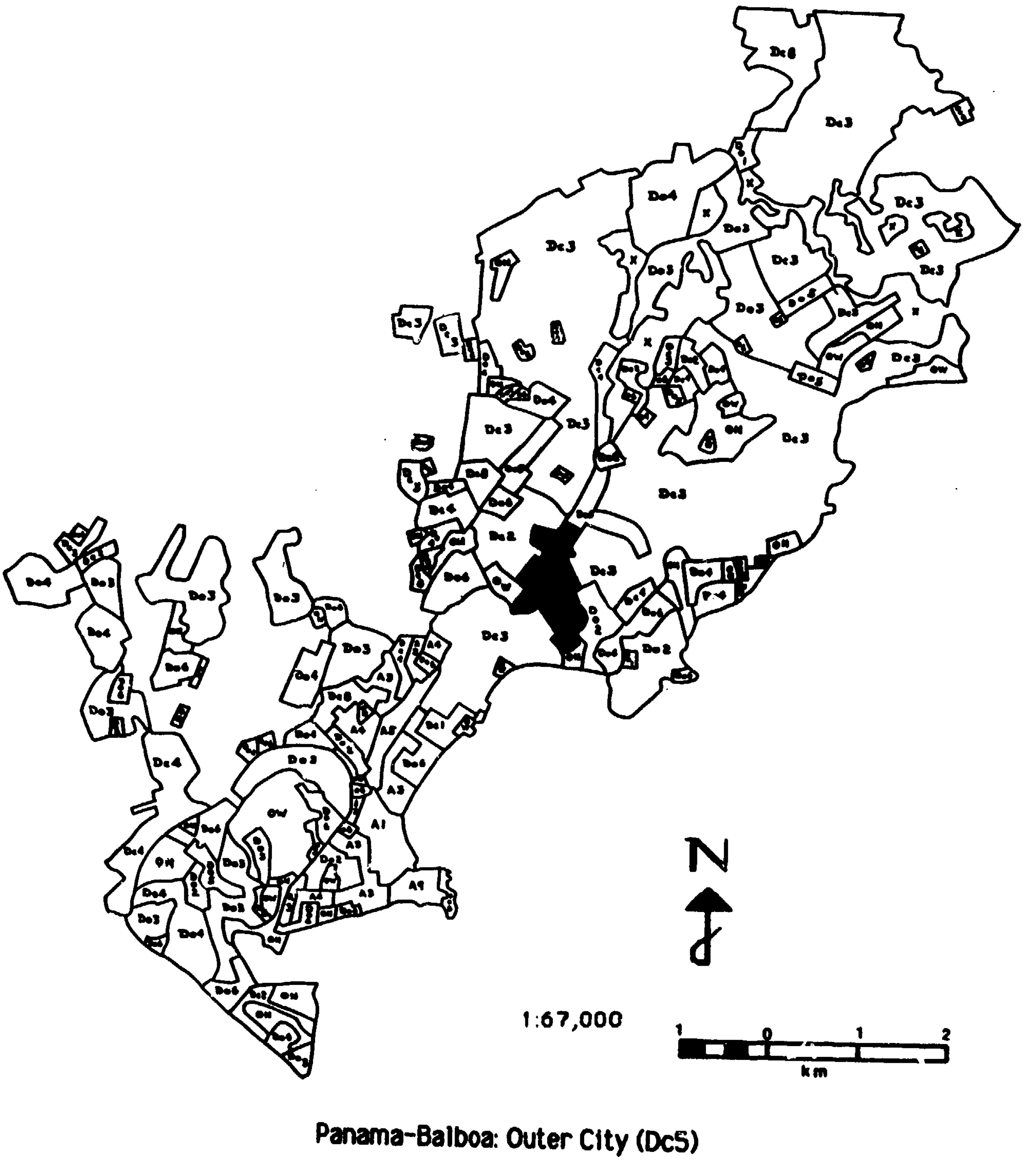
Panama-Balboa: Apartments, >75% ground coverage (Dc2)



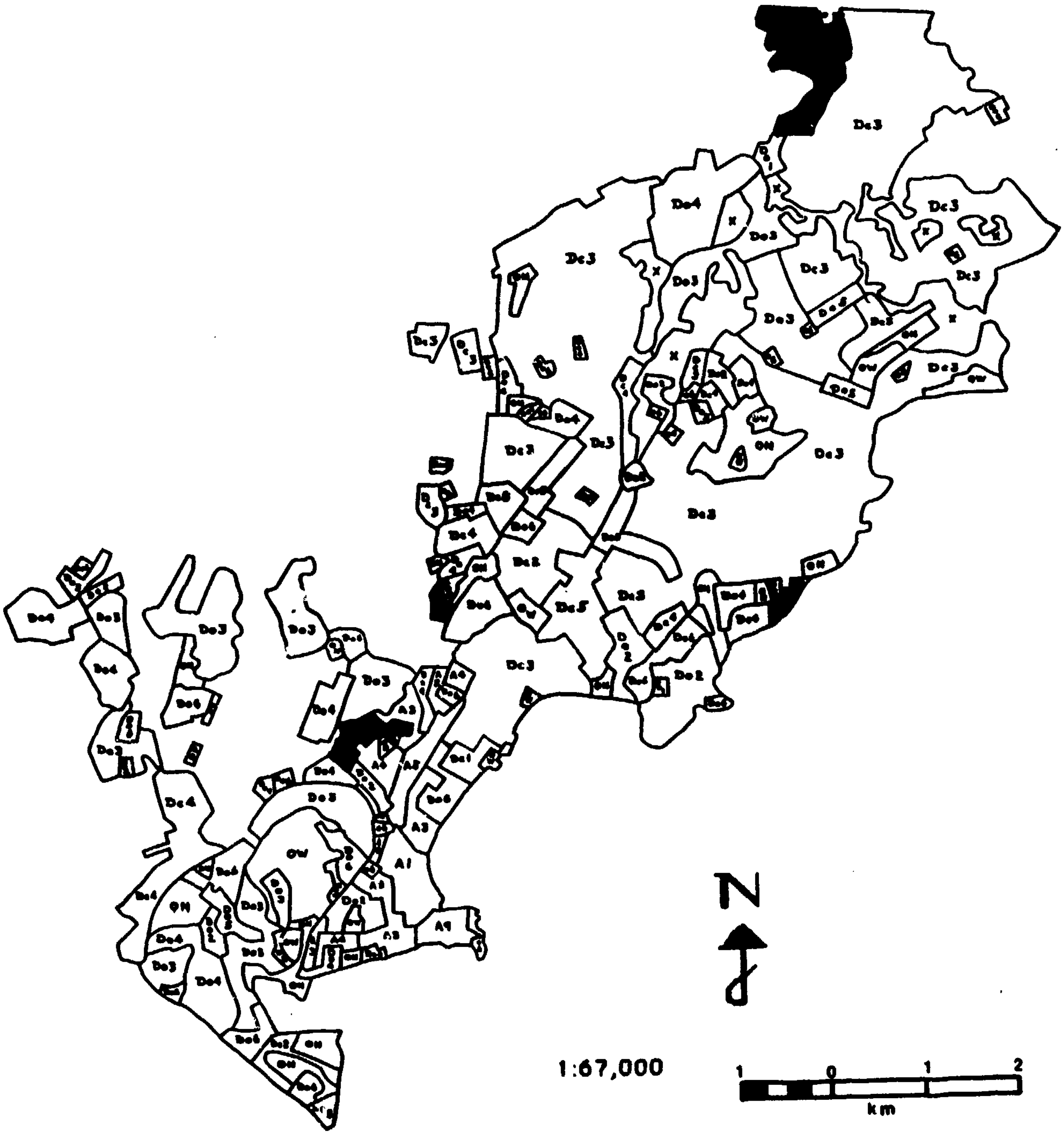
Panama-Balboa: Houses, >75% ground coverage (Dc3)



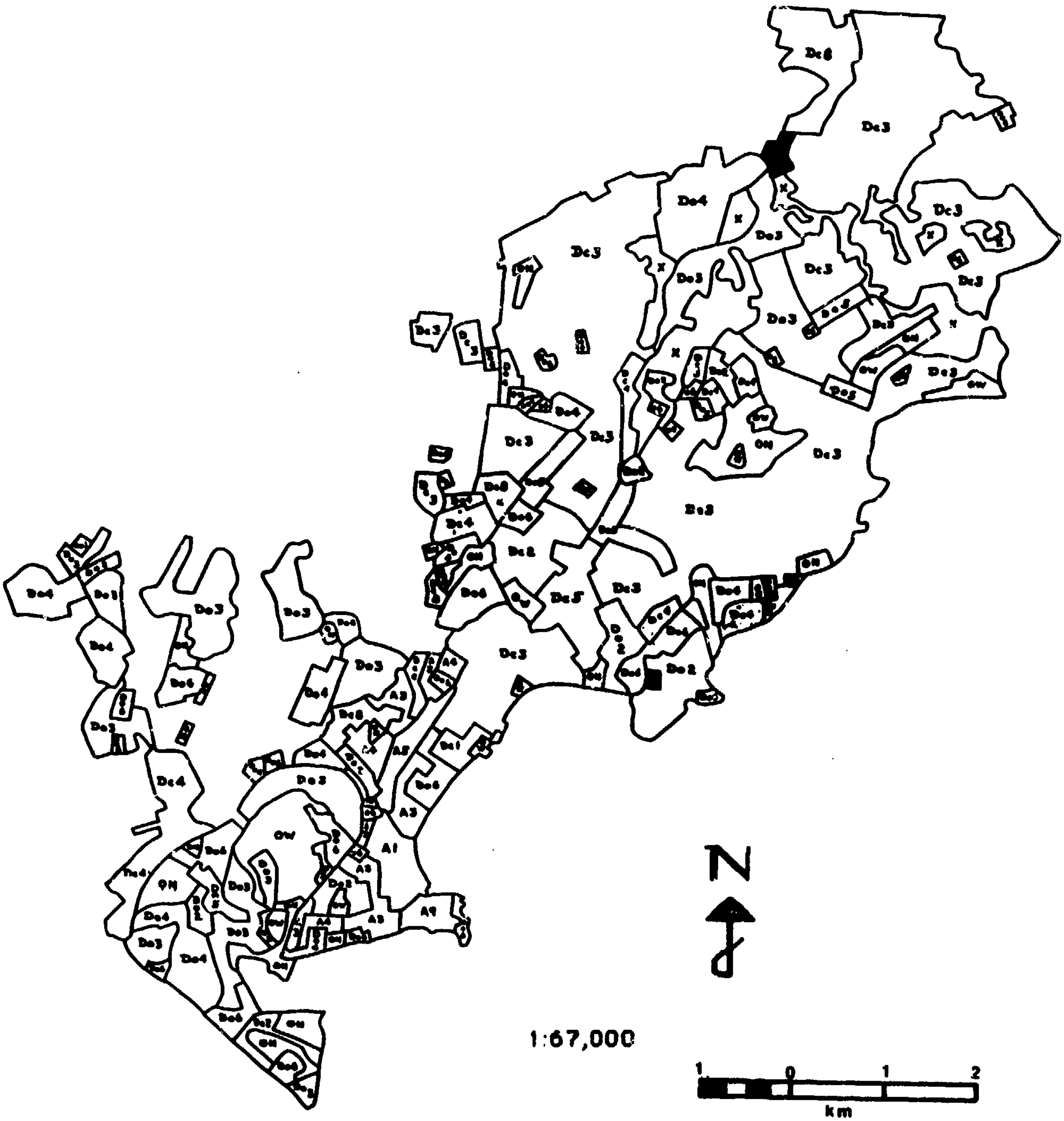
Panama-Balboa: Industrial/storage, RR or dock-related (Dc4)



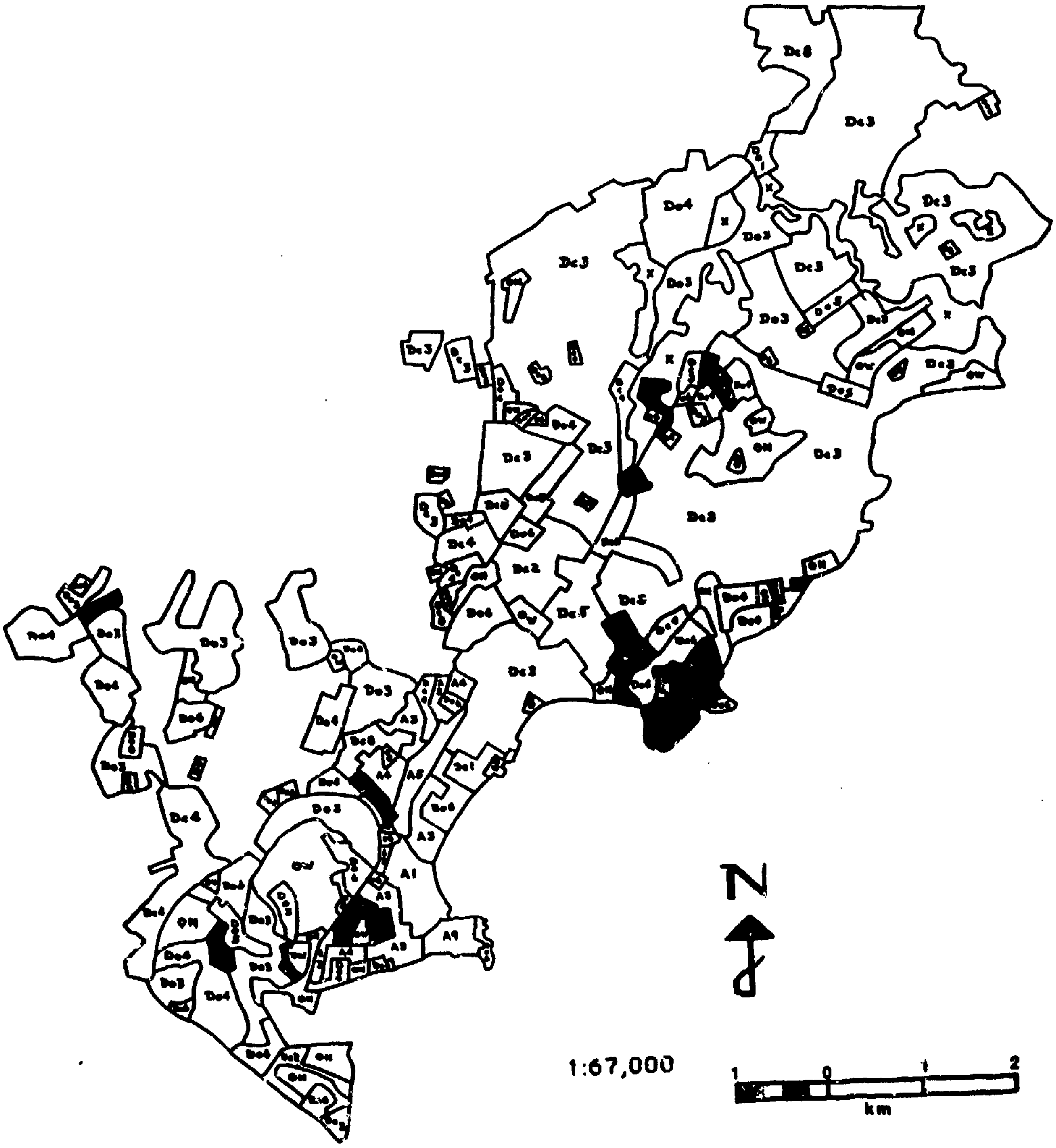
Panama-Balboa: Outer City (DcS)



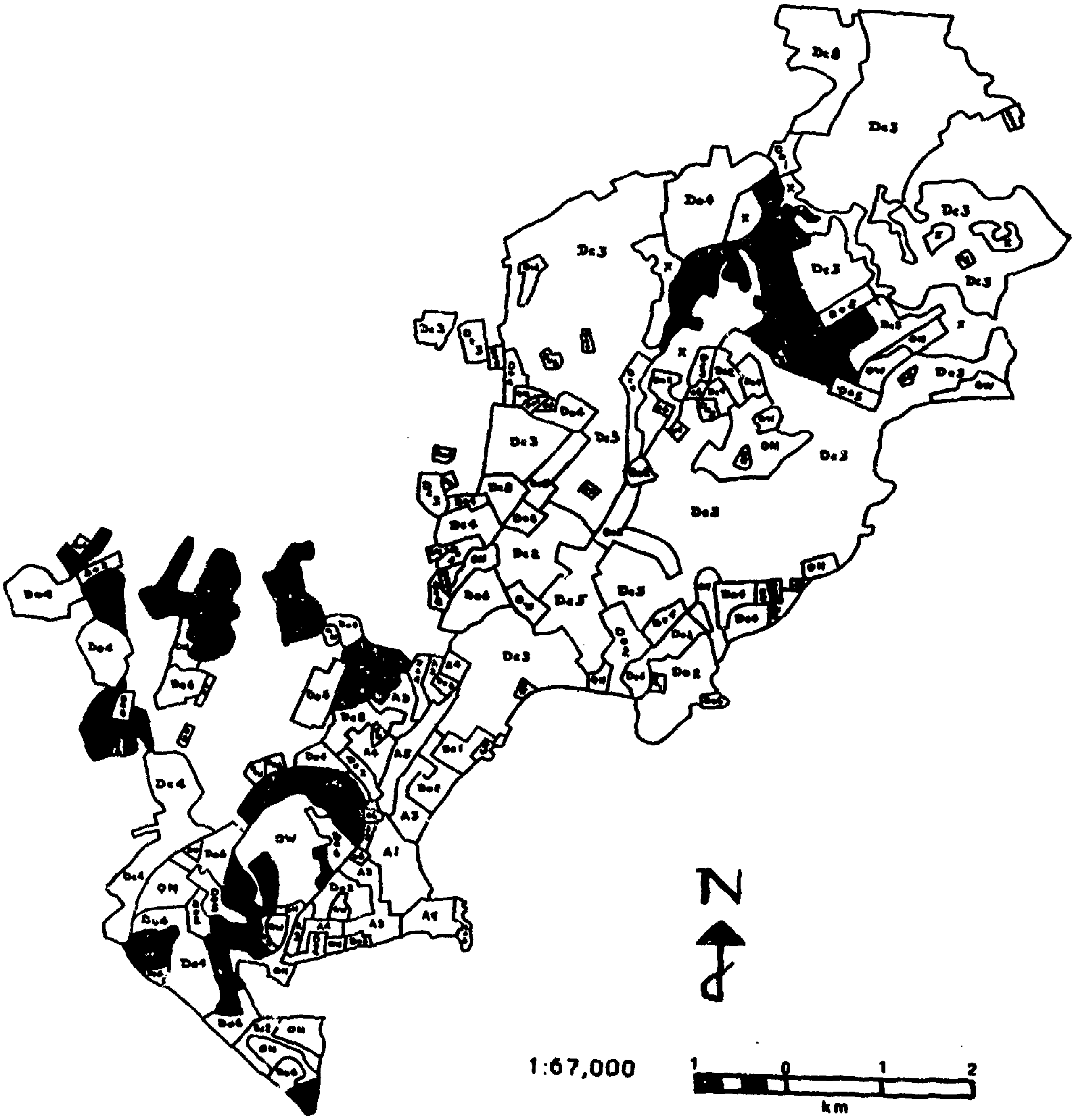
Panama-Balboa: Shanty Towns (Dc8)



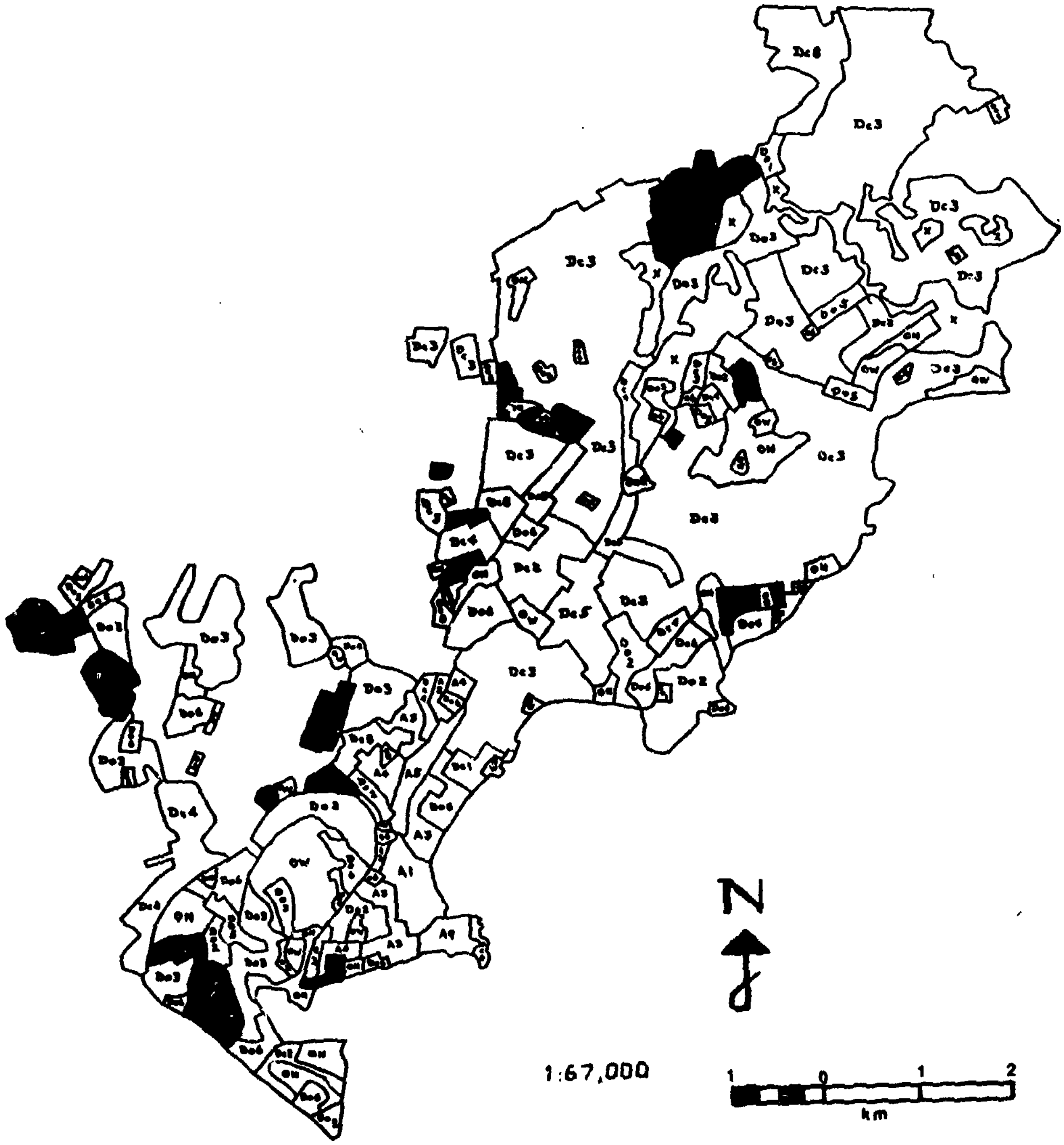
Panama-Balboa: Shopping Centers (Do1)



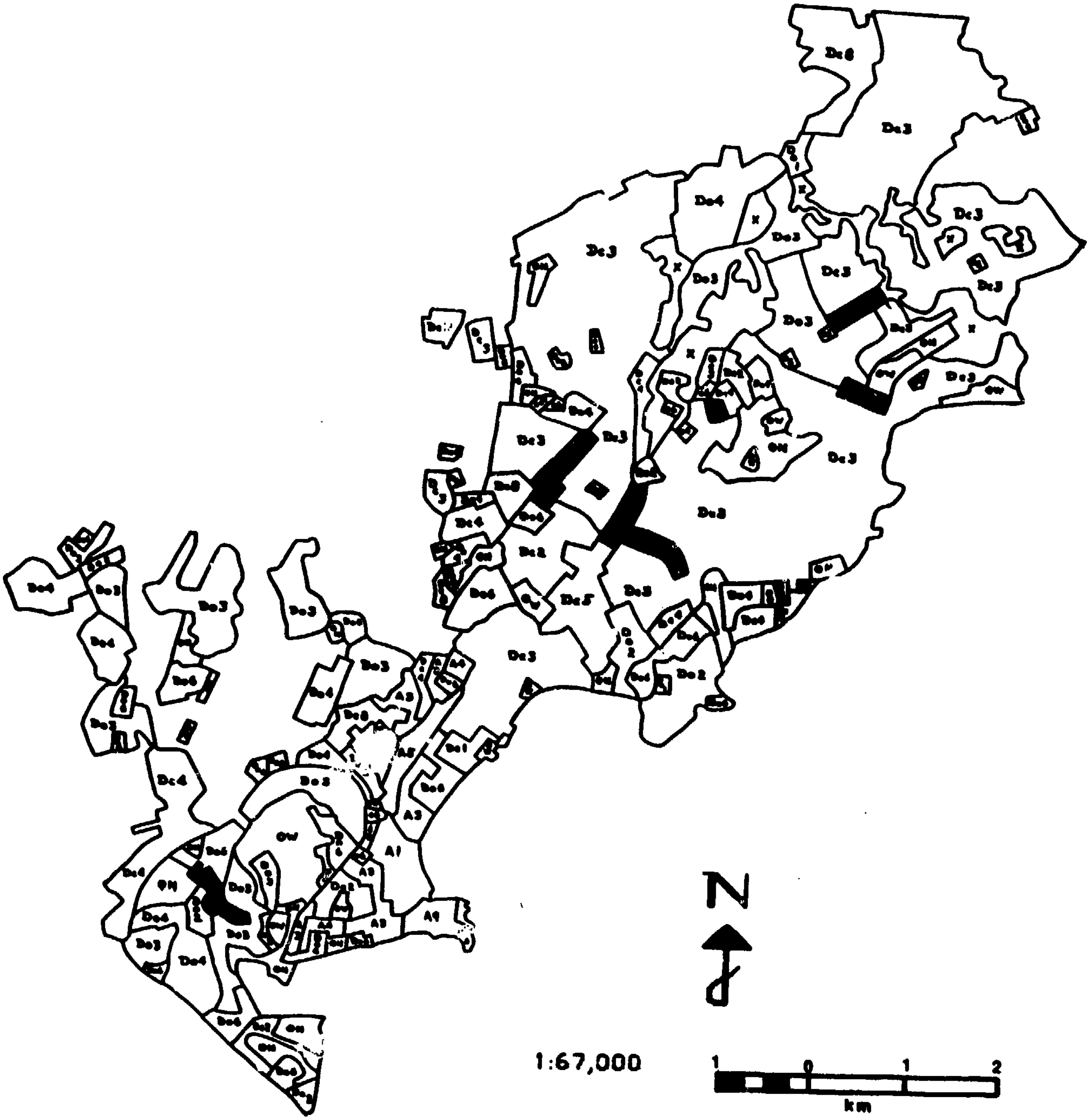
Panama-Balboa: Apartments, <75% ground coverage (Do2)



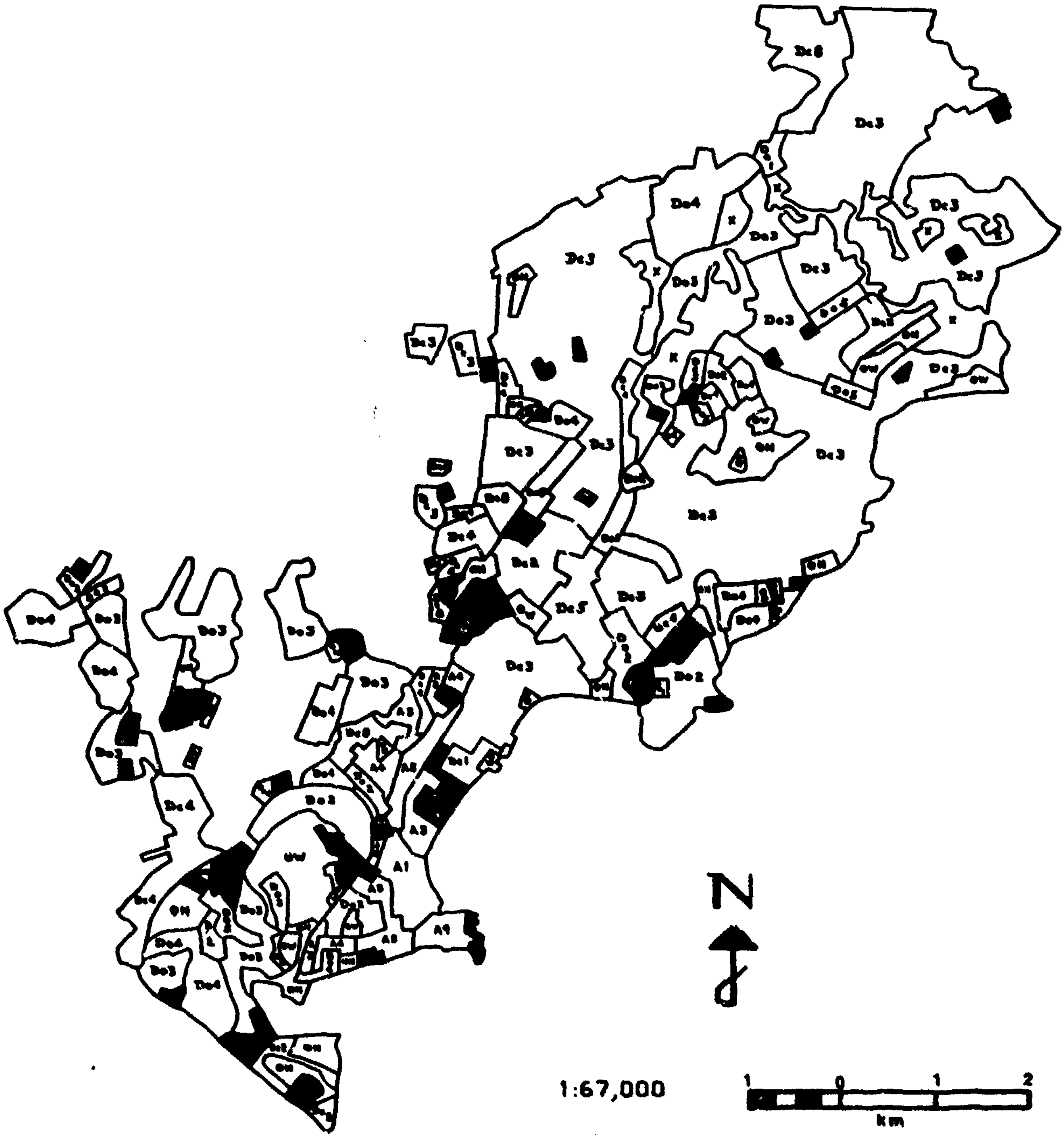
Panama-Balboa: Houses, <75% ground coverage (Do3)



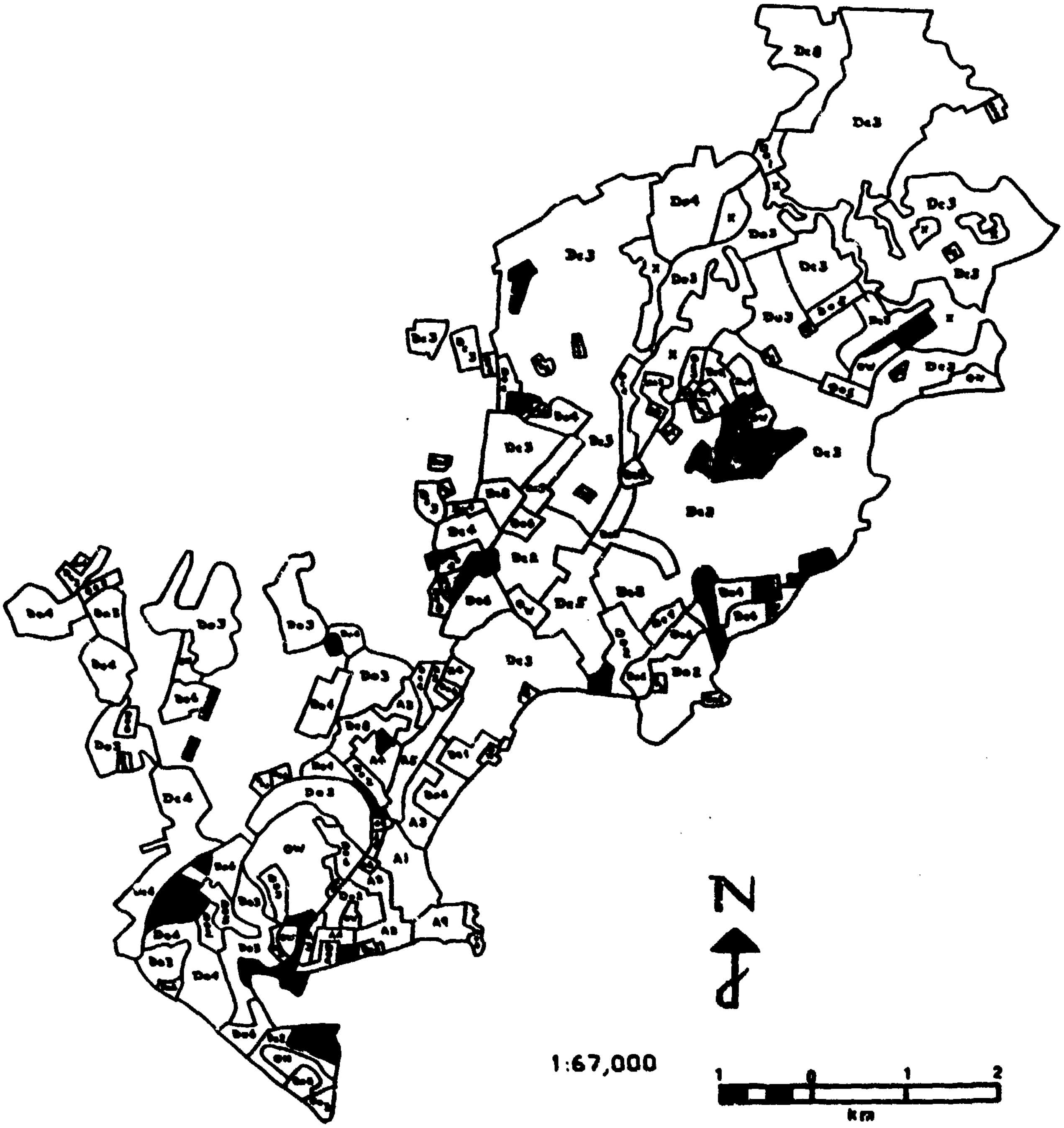
Panama-Balboa: Industrial/storage, truck-related (Do4)



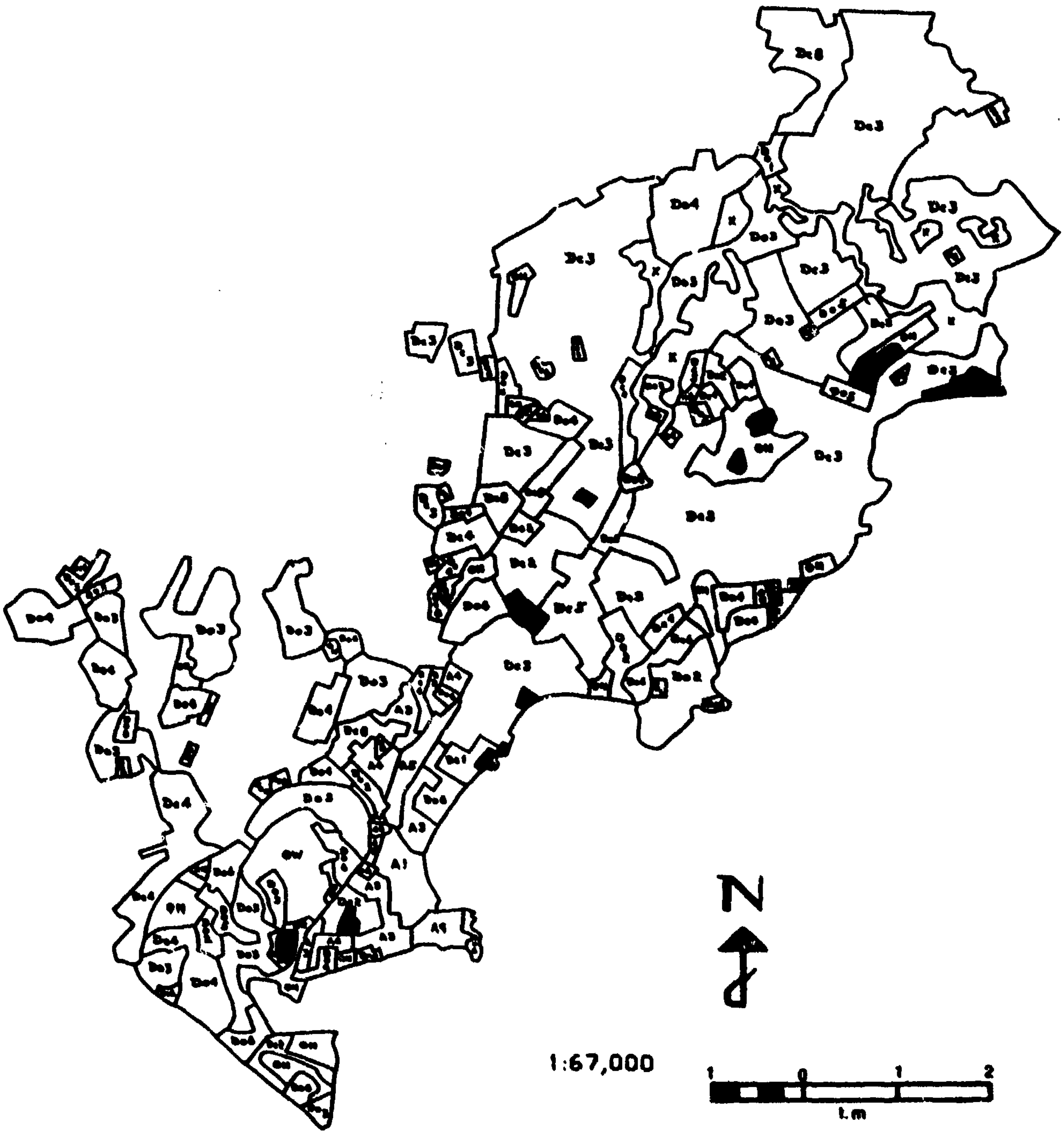
Panama-Balboa: Commercial Ribbons (Do5)



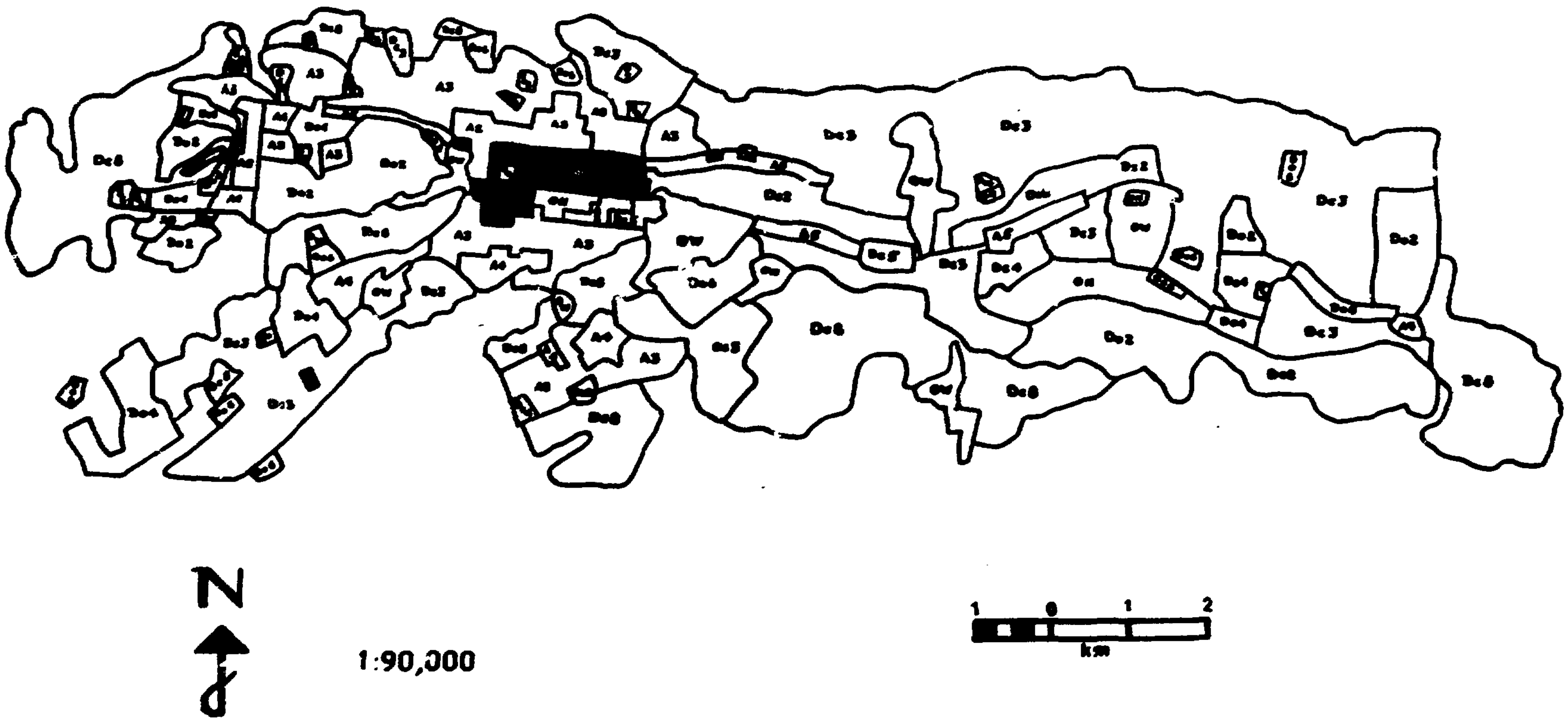
Panama-Balboa: Administrative/cultural (Do6)



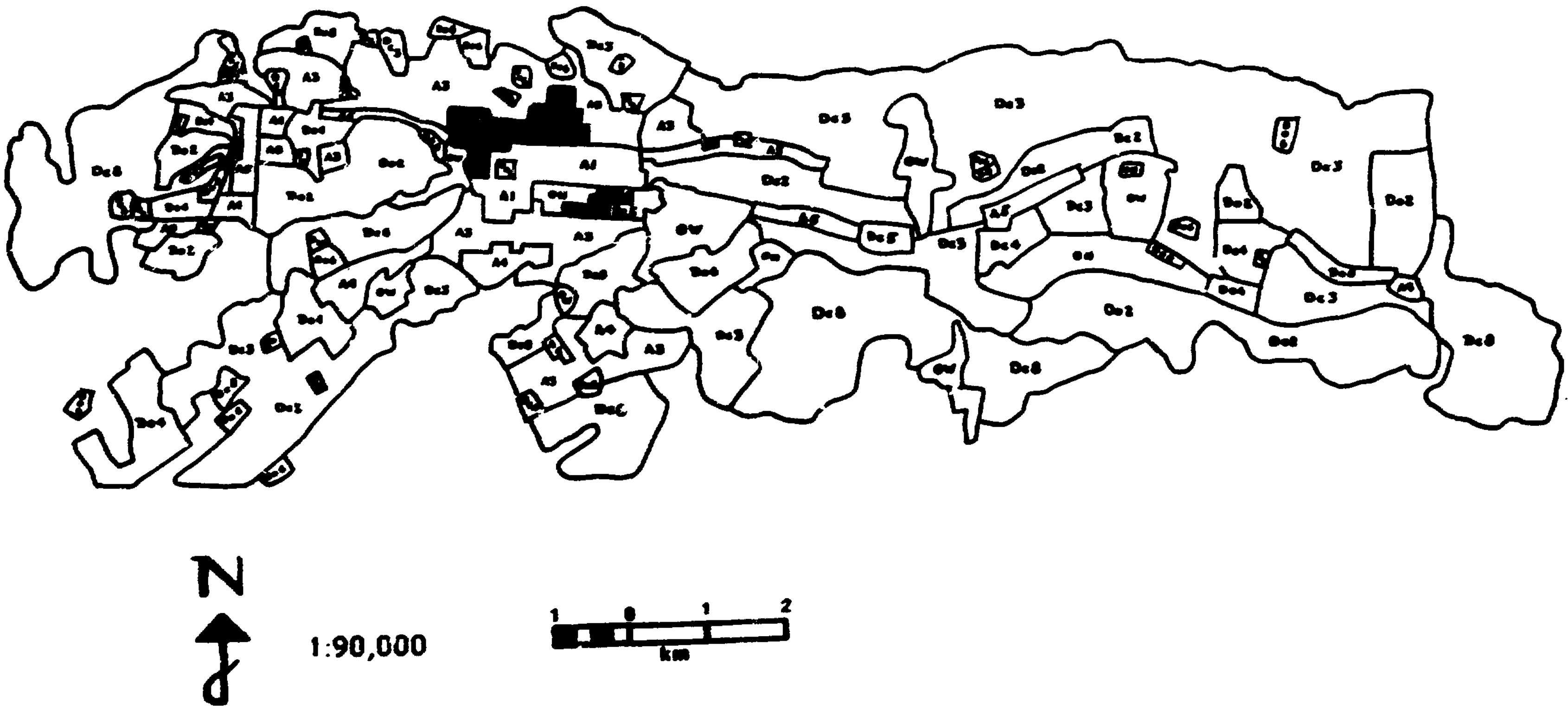
Panama-Balboa: Open Space, not built upon (ON)



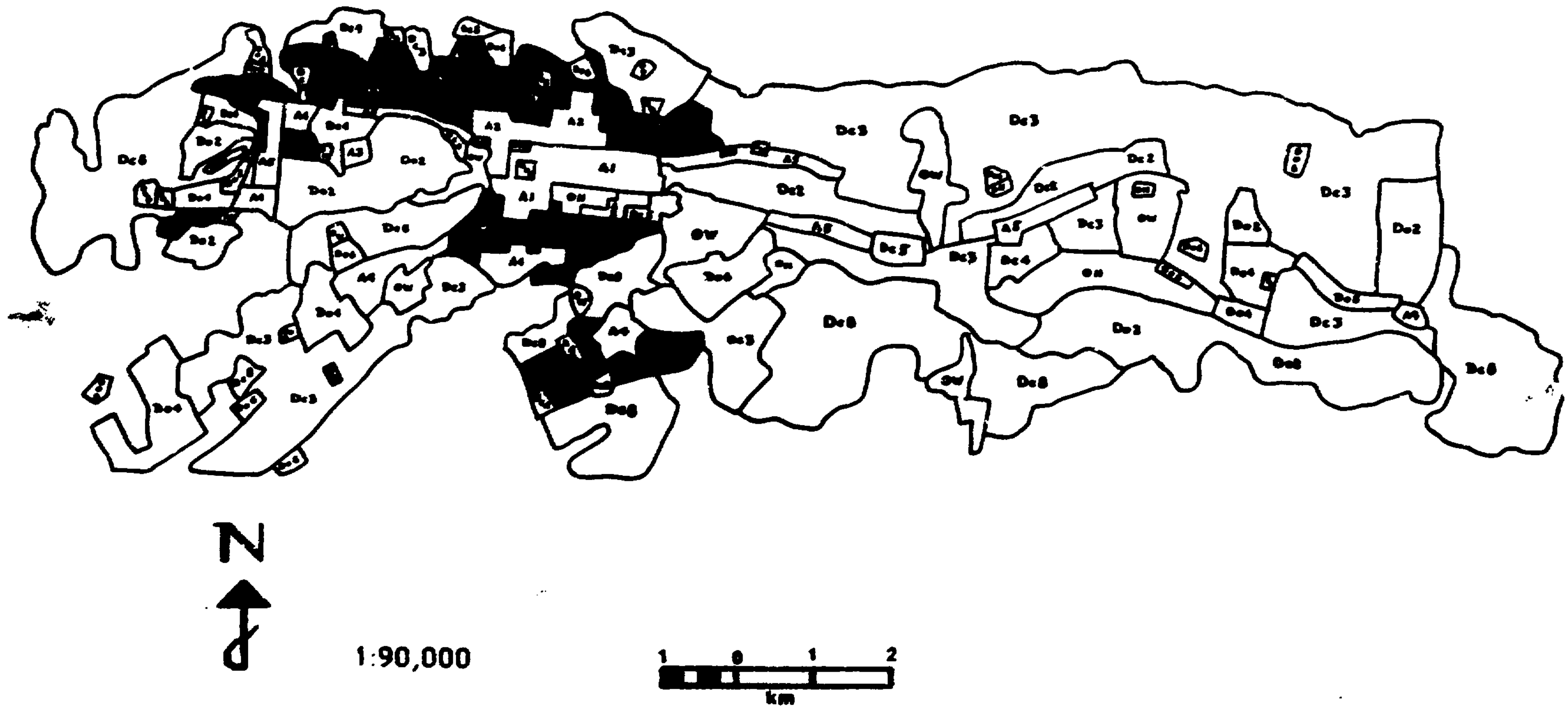
Panama-Balboa: Open Space, wooded, not built upon (OW)



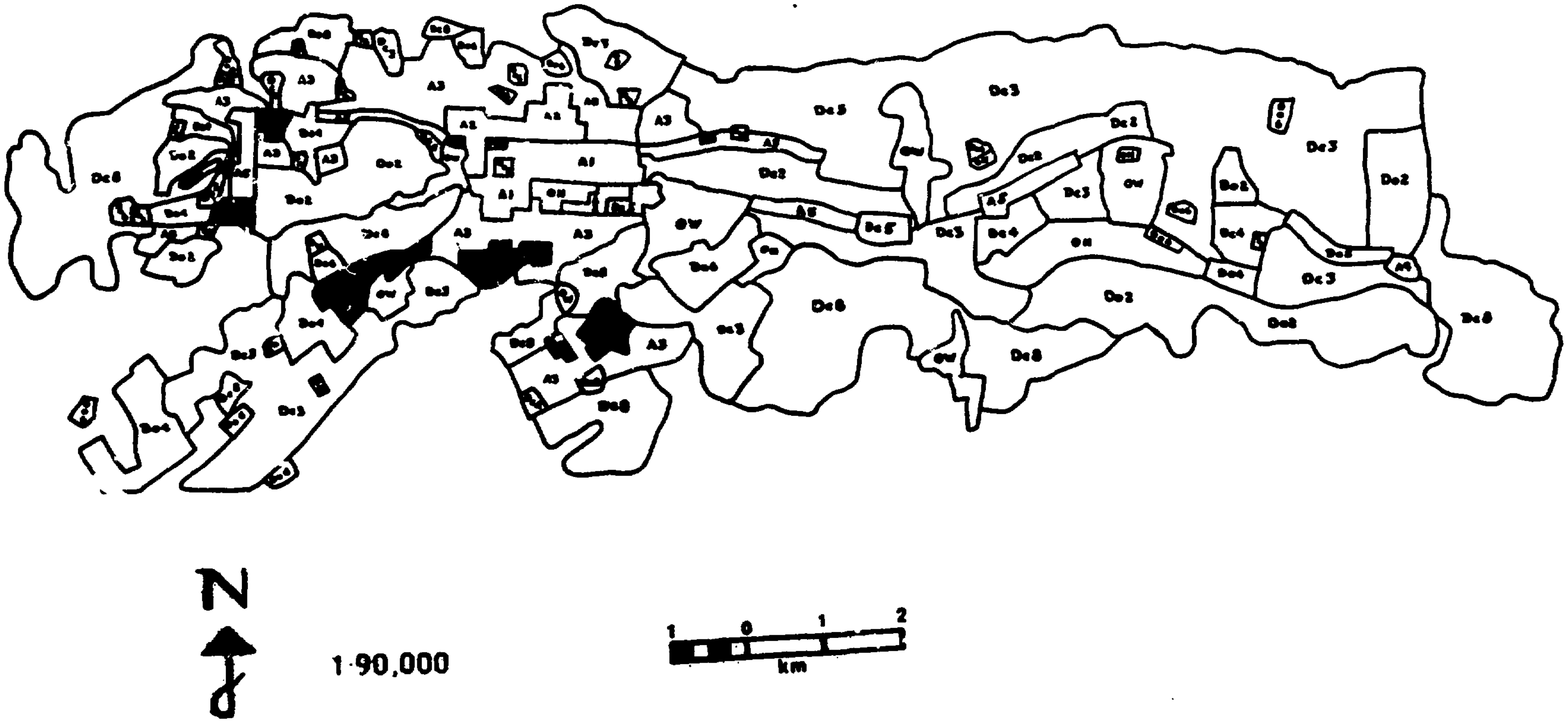
Caracas: Core Area (A1)



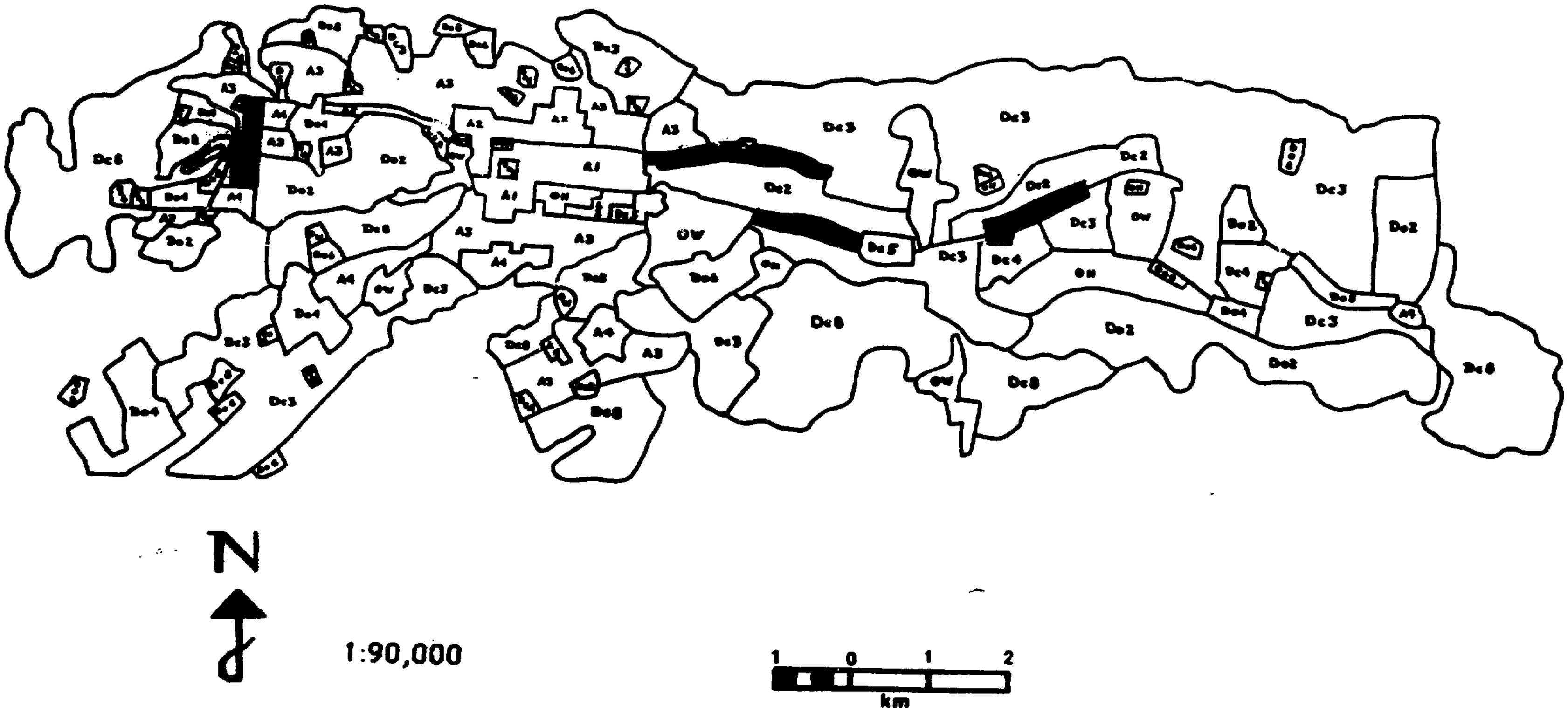
Caracas: Apartments/hotels, core periphery (A2)



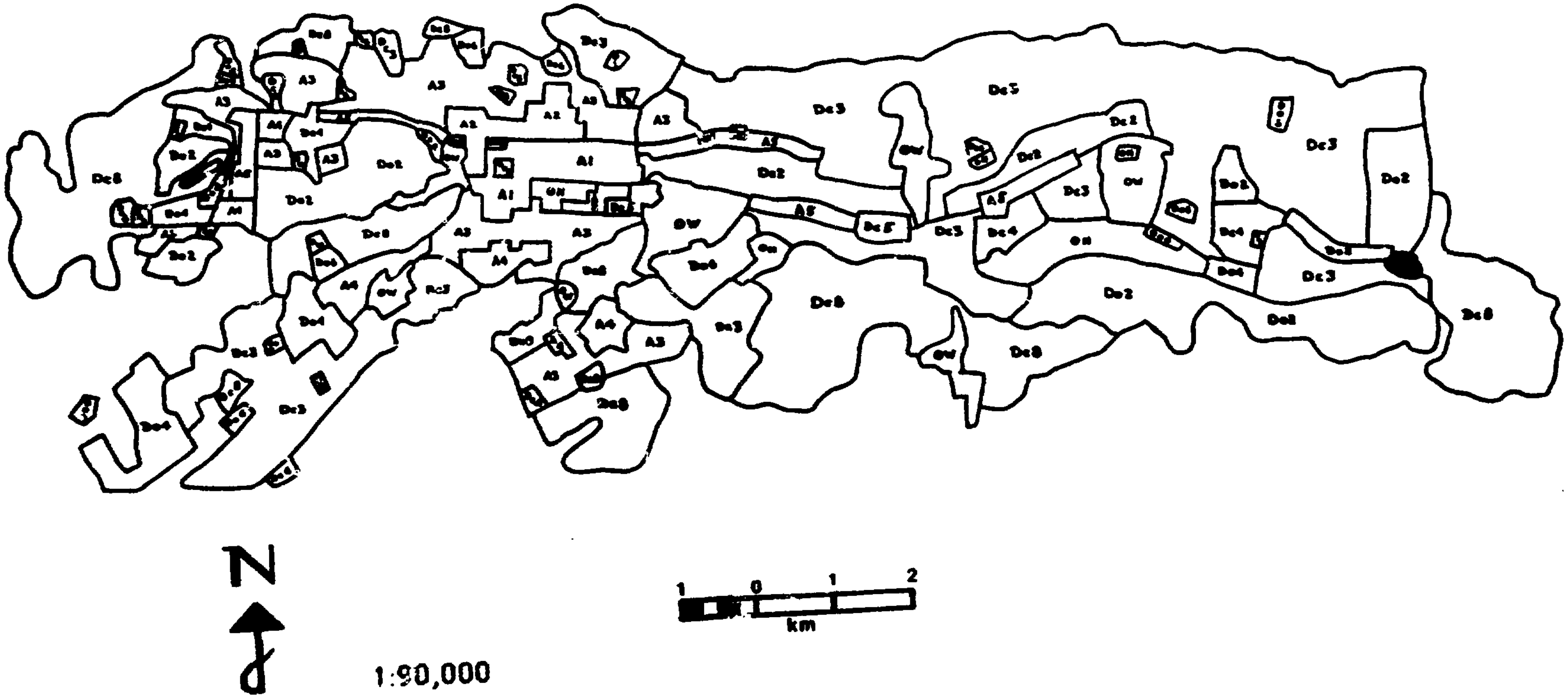
Caracas: Apartments/row houses (A3)



Caracas: Industrial/storage, full urban form (A4)



Caracas: Old Commercial Ribbons (A5)



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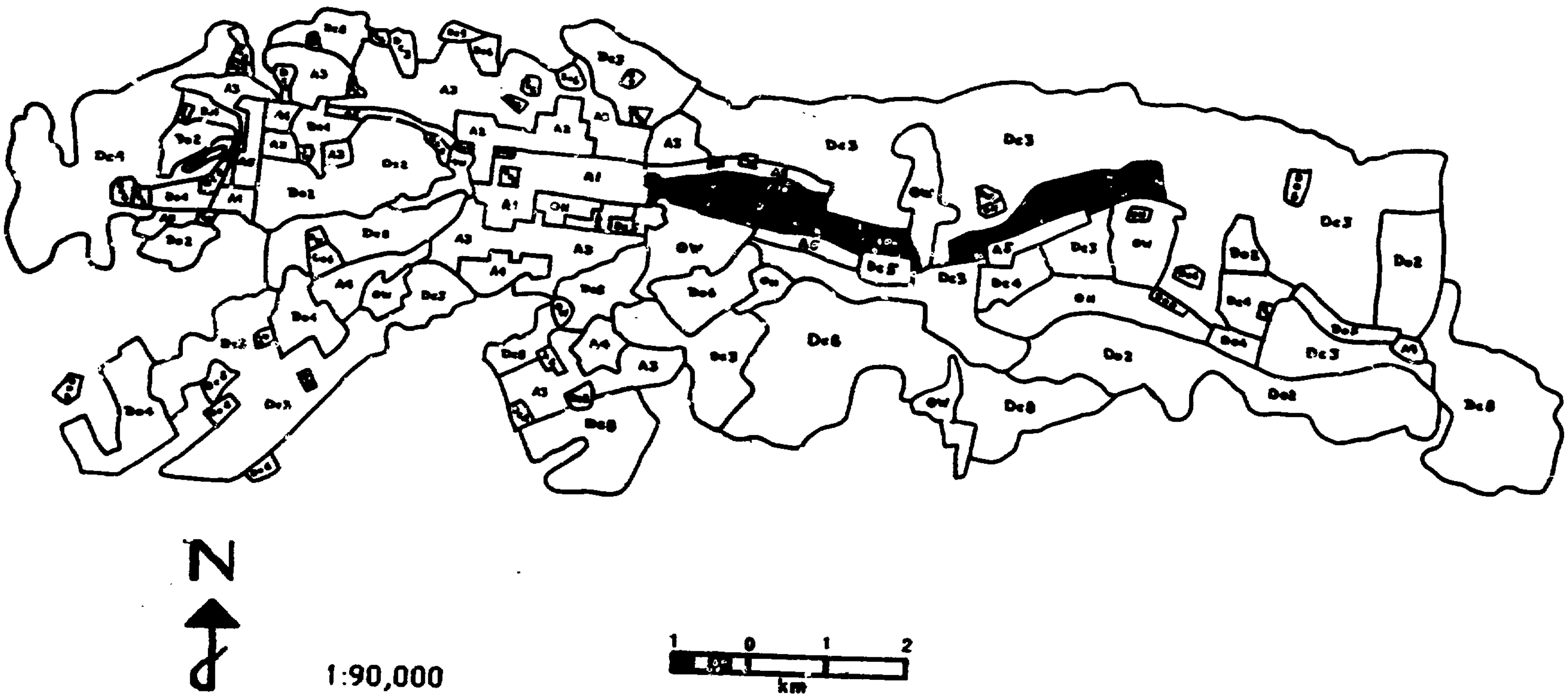
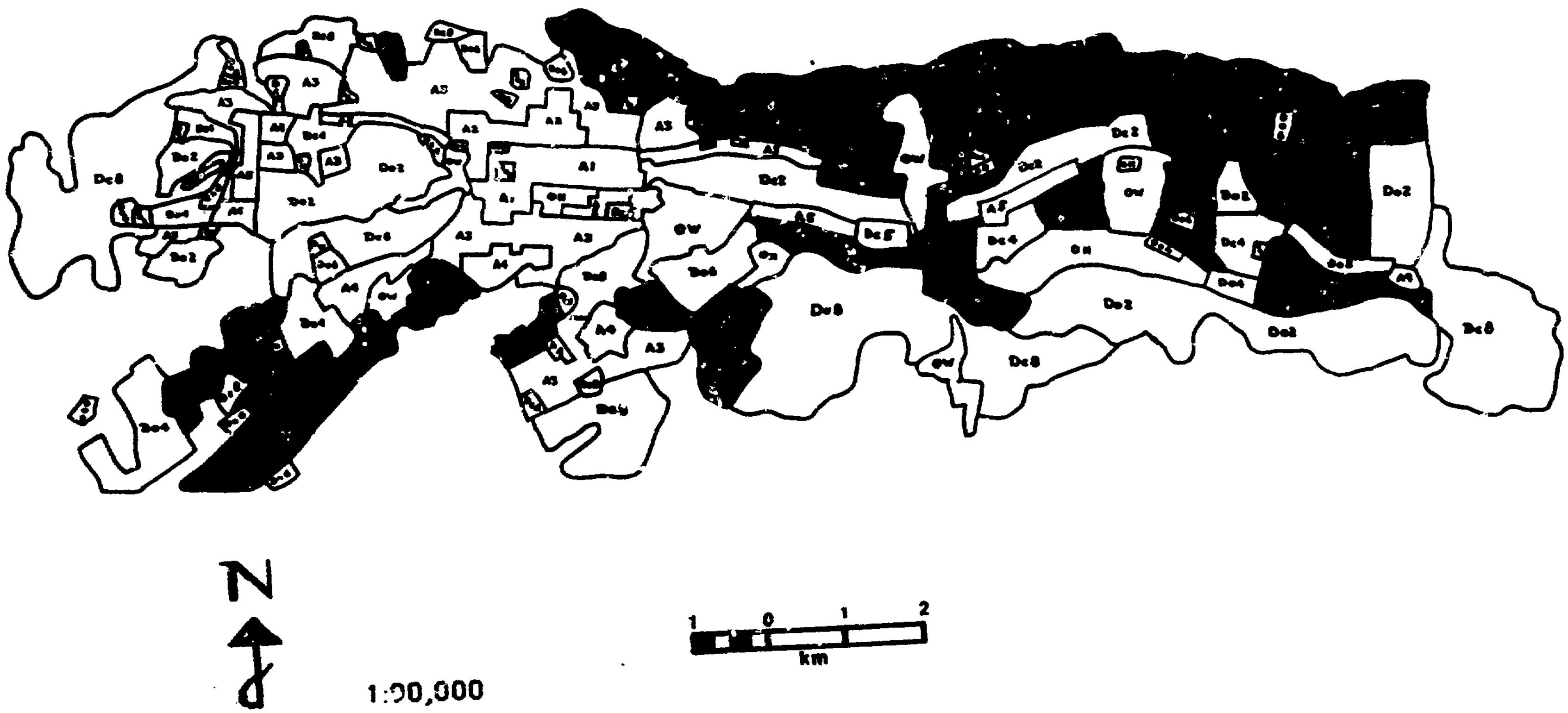
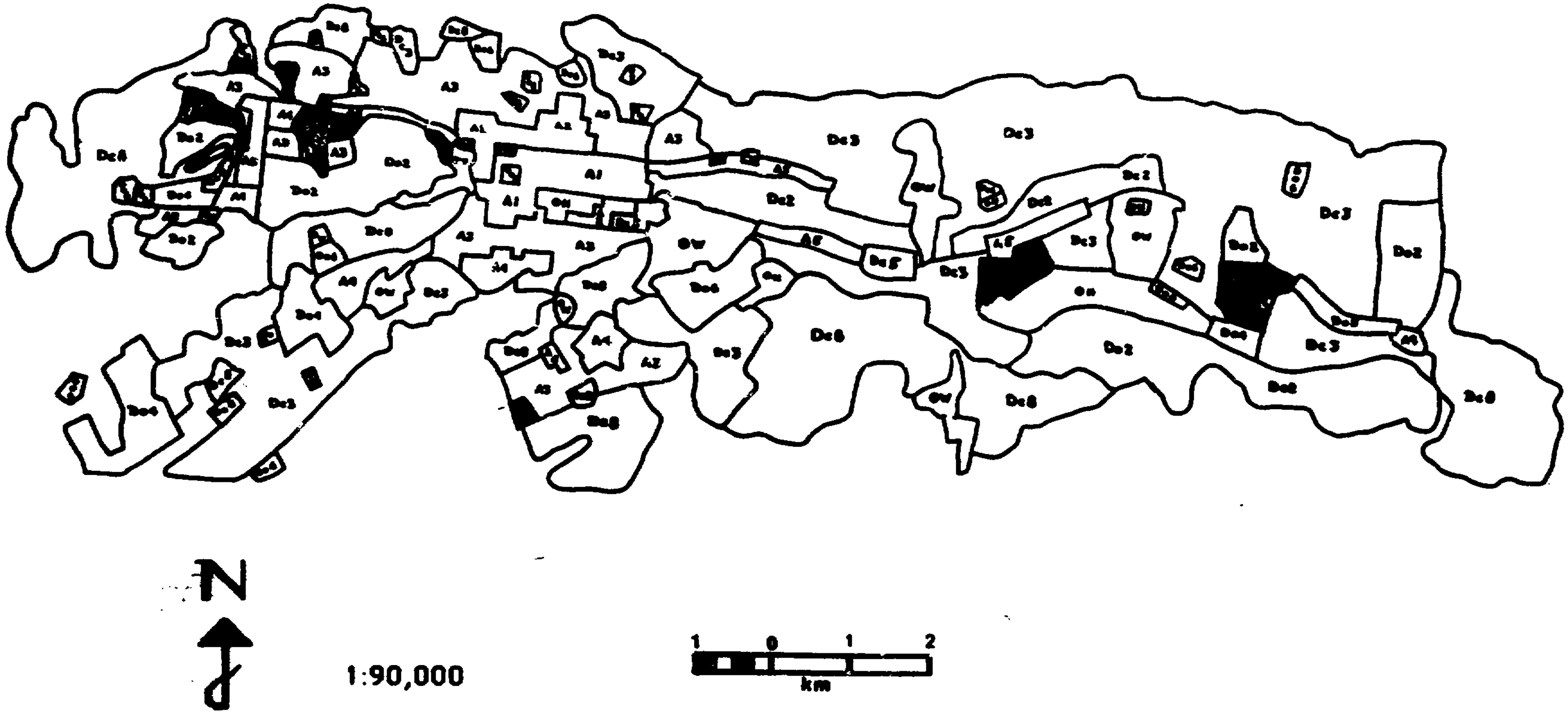
Caracas: Old Core, vestigial (A9)



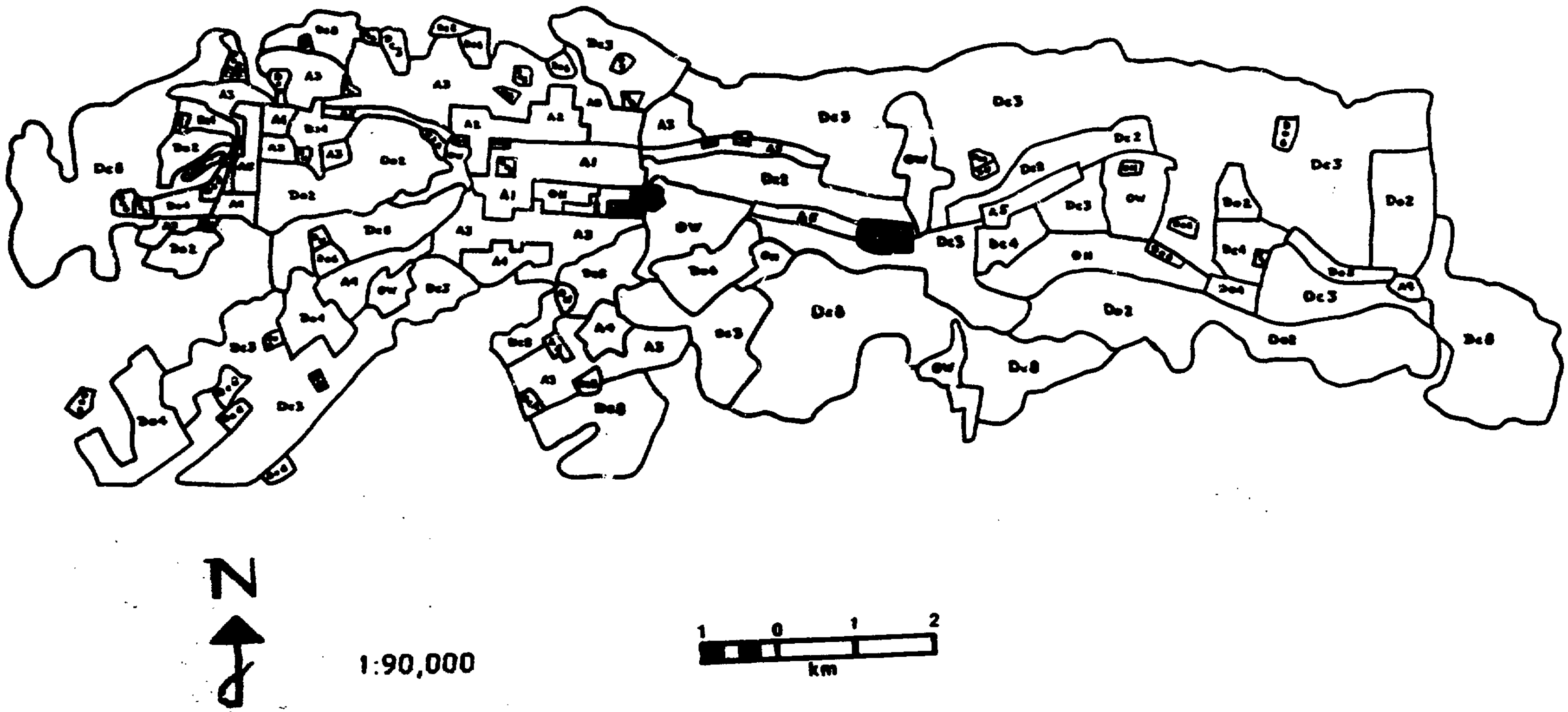
Caracas: Apartments, >75% ground coverage (Dc2)



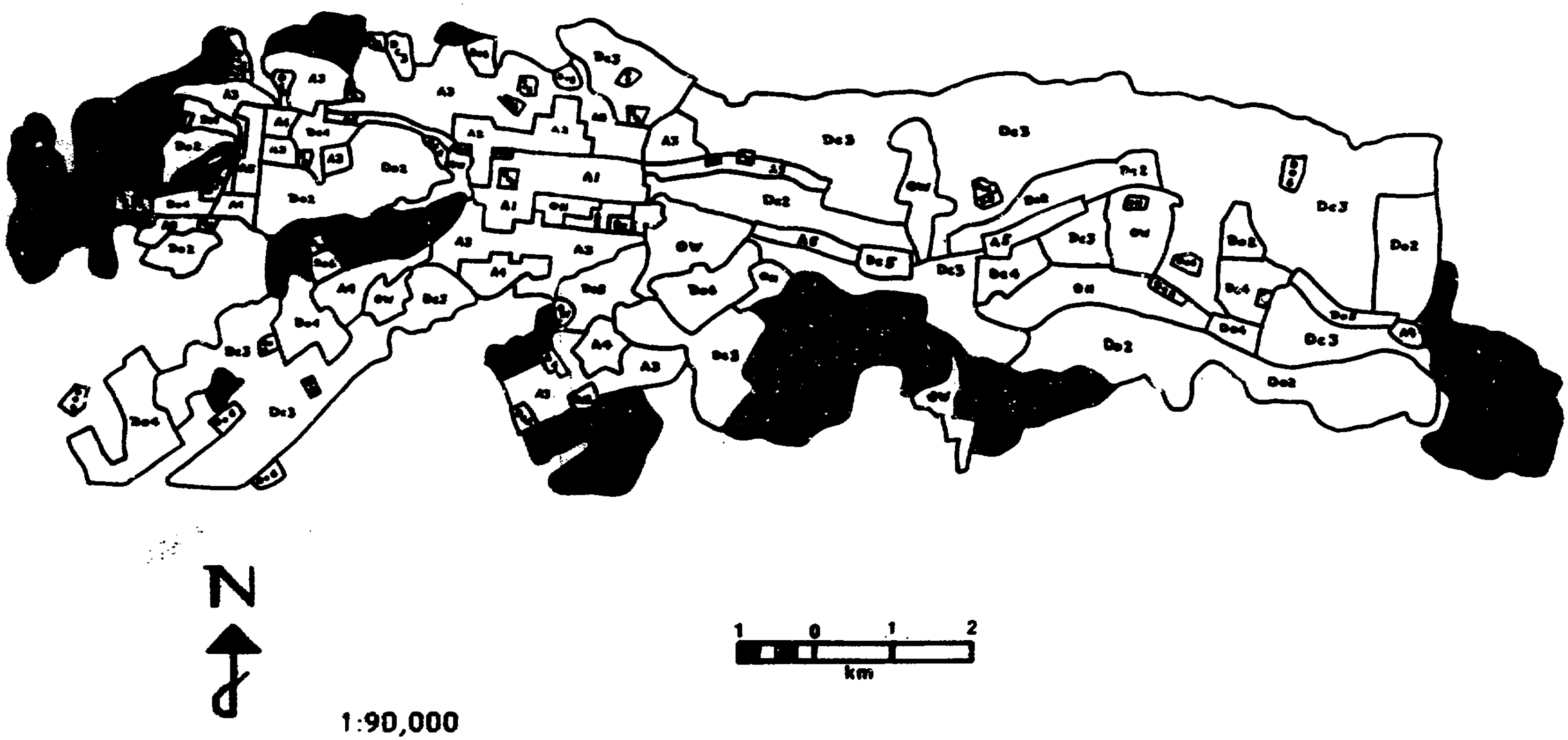
Caracas: Houses, >75% ground coverage (Dc3)



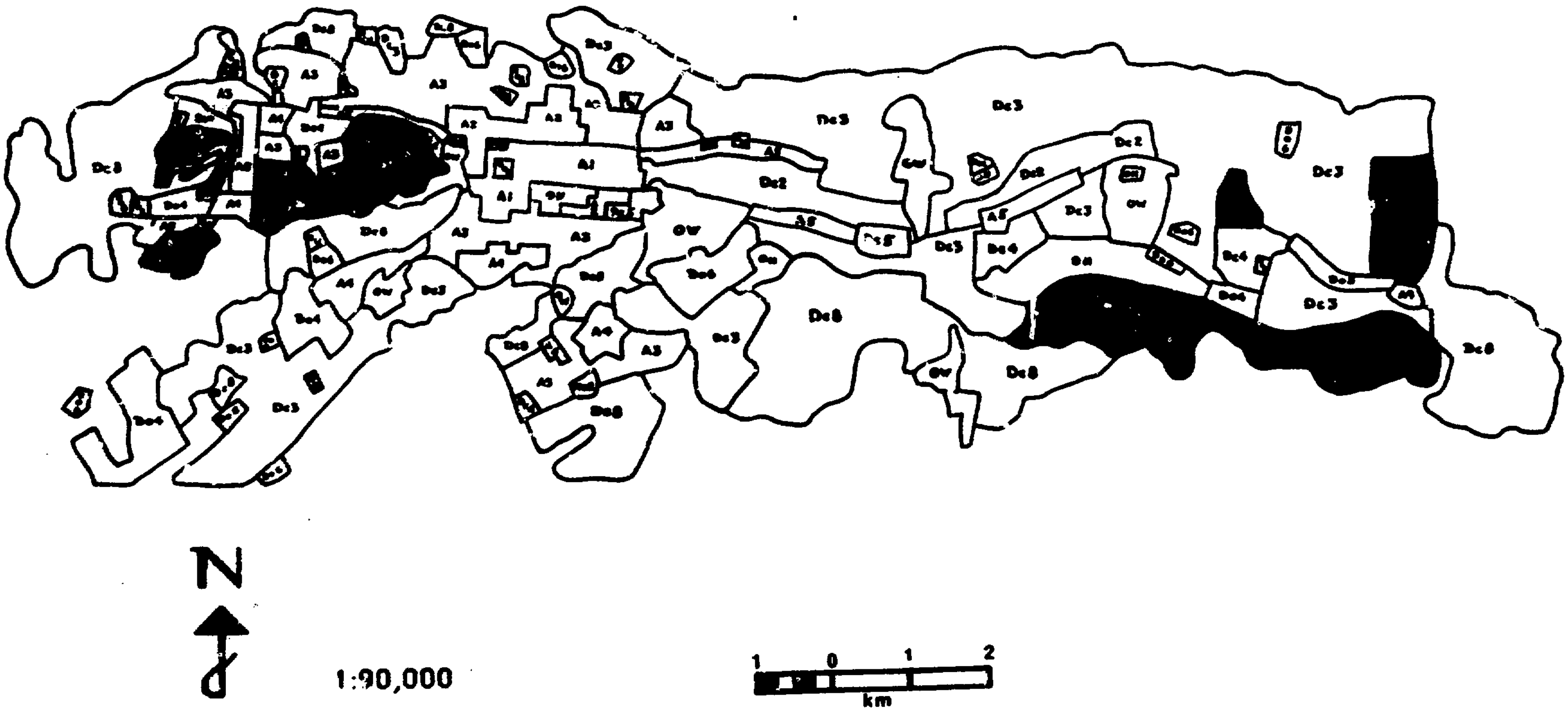
Caracas: Industrial/storage, RR or dock-related (Dc4)



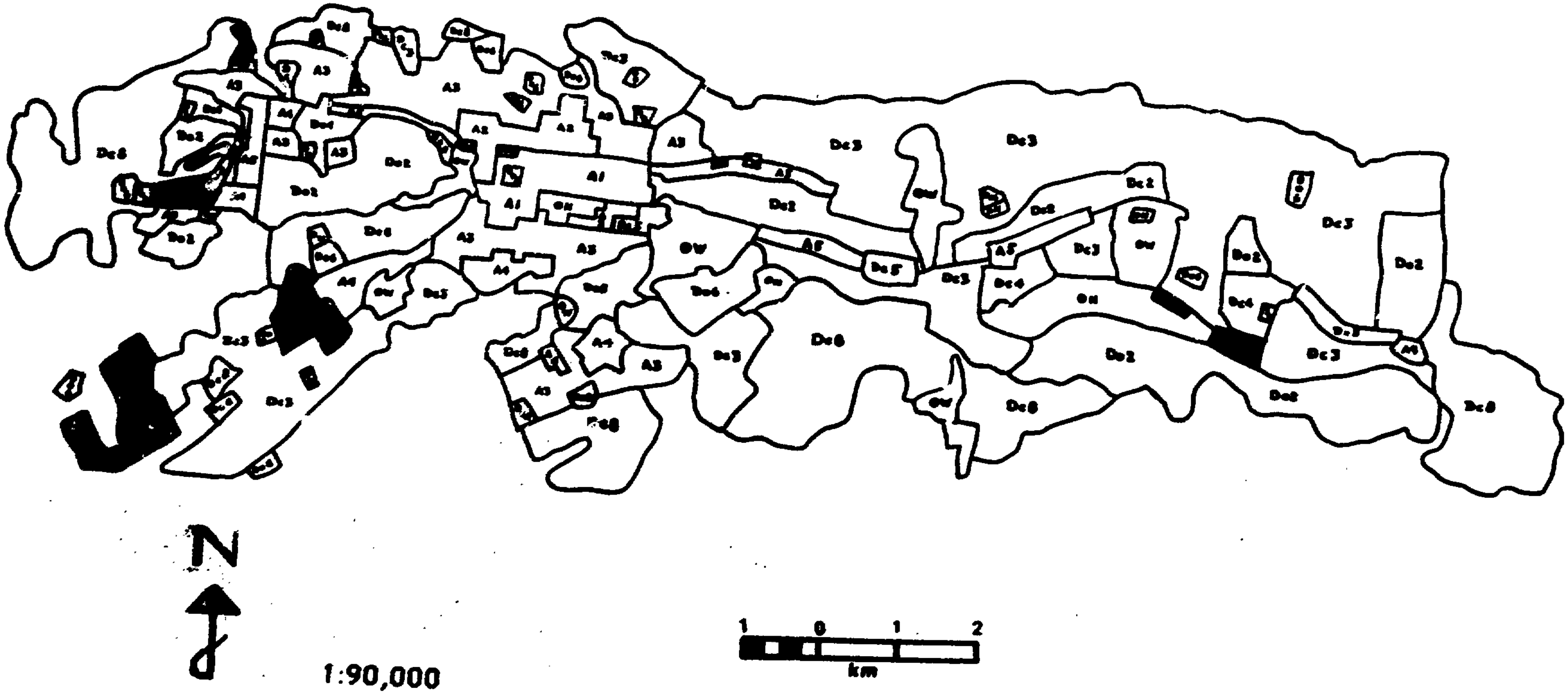
Caracas: Outer City (Dc5)



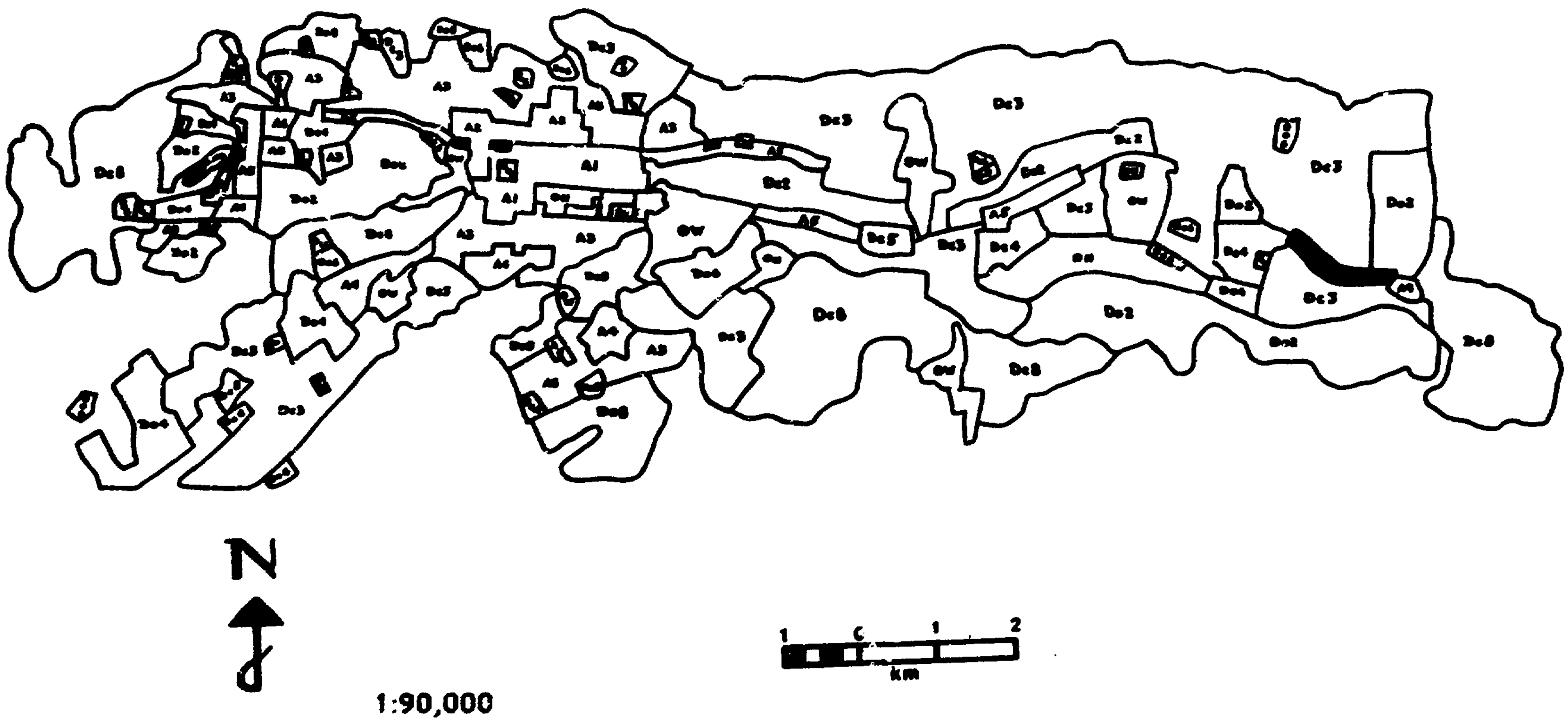
Caracas: Shanty Towns (Dc8)



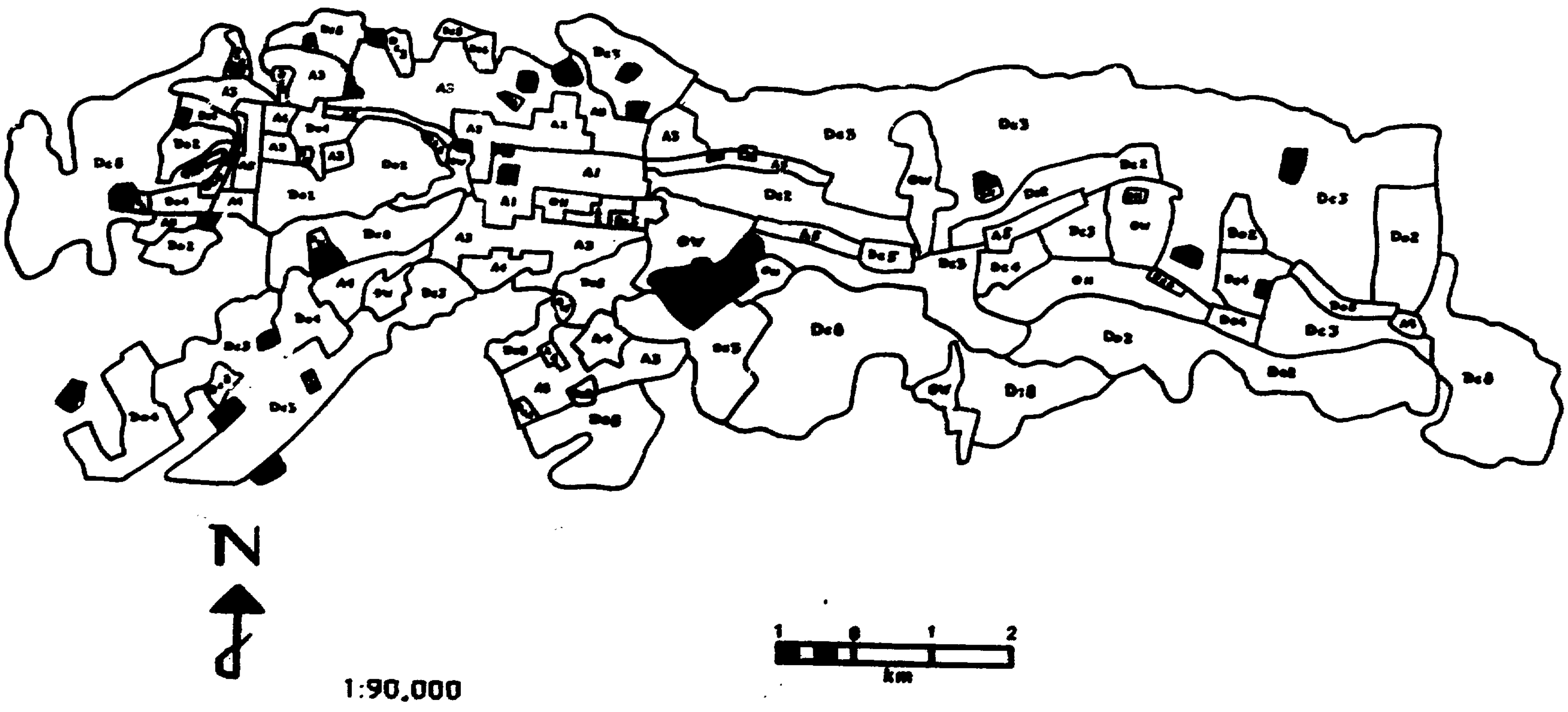
Caracas: Apartments, <75% ground coverage (Do2)



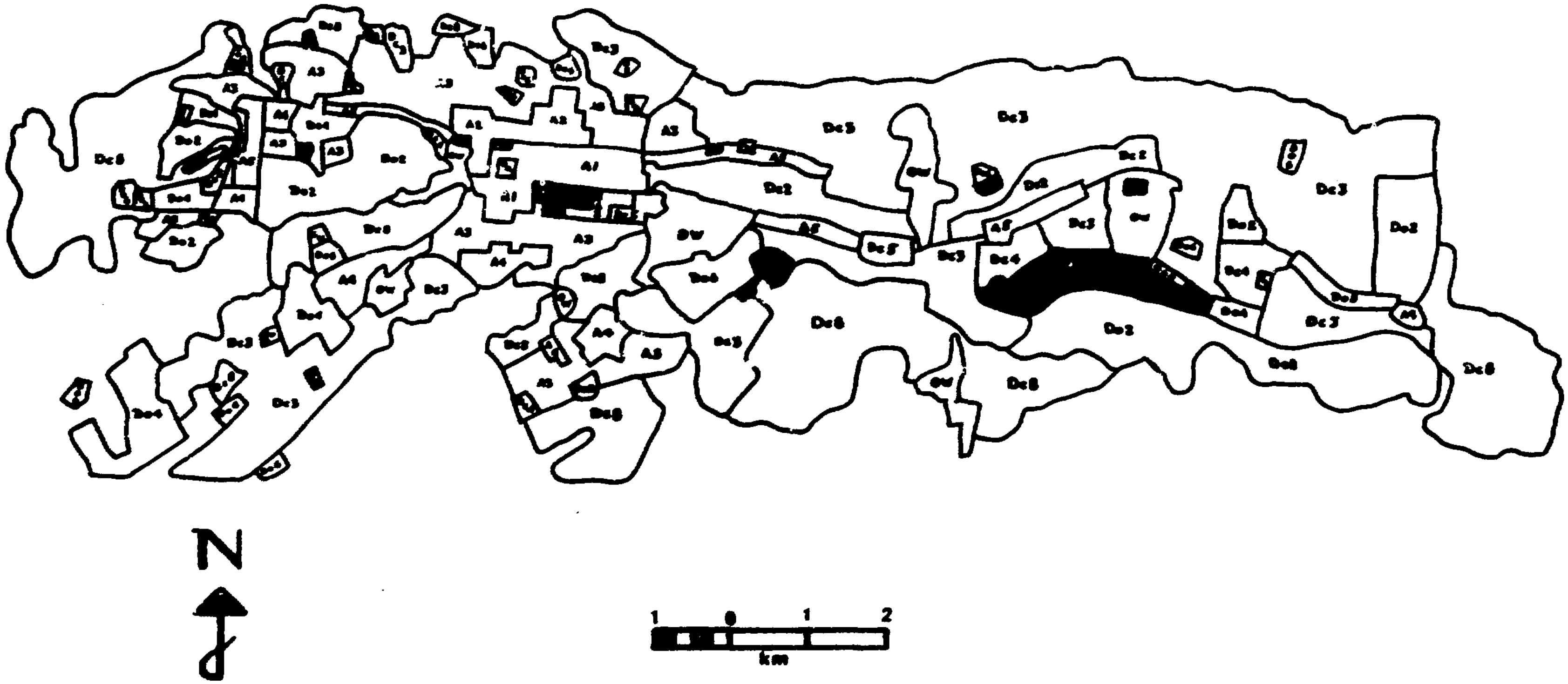
Caracas: Industrial/storage, truck-related (Do4)



Caracas: New Commercial Ribbons (Do5)



Caracas: Administrative/cultural (Do6)



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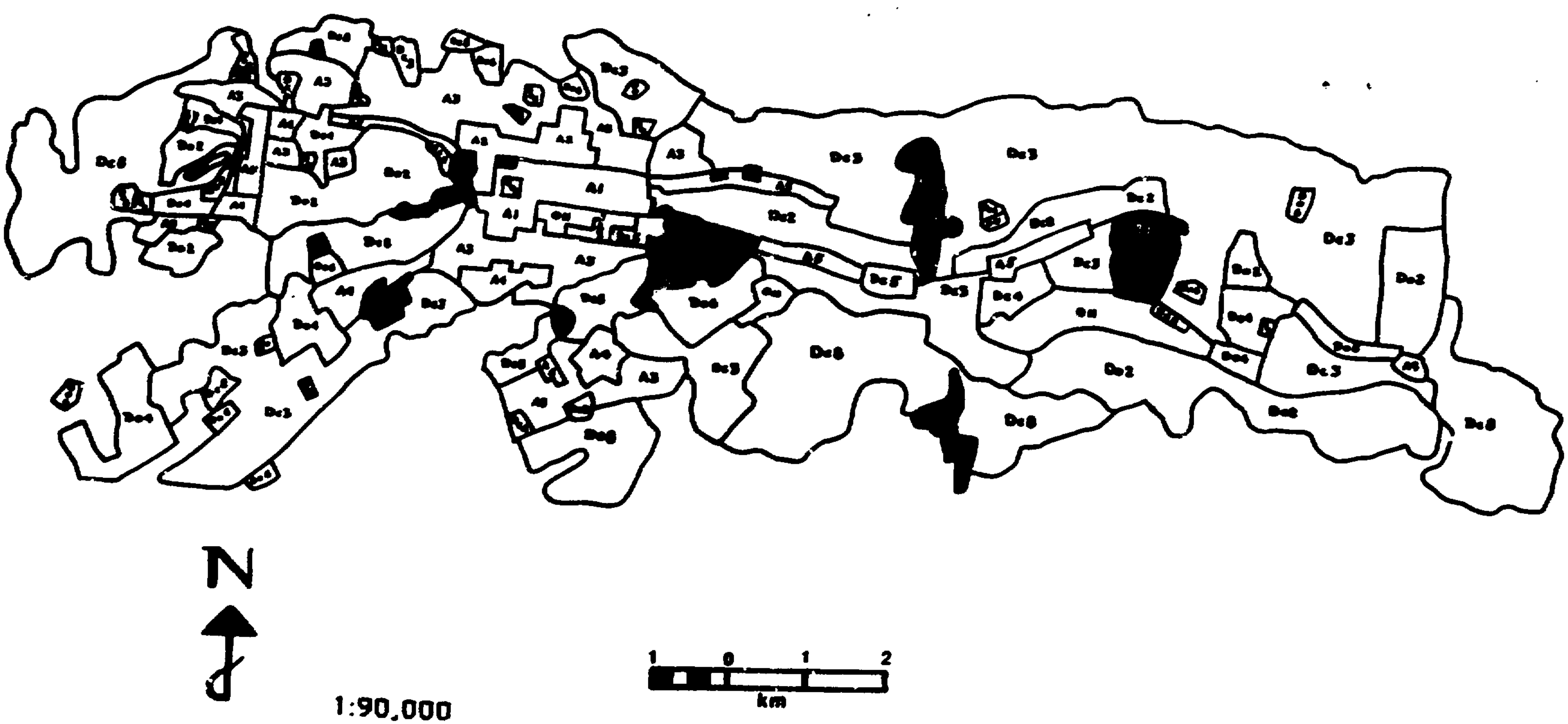
Caracas: Open Space, not built upon (ON)



Caracas: Open Space, wooded, not built upon (OW)

*U.S. GOVERNMENT PRINTING OFFICE:1987-180-991:60428